Metals and Alloys

THE MAGAZINE OF METALLURGICAL ENGINEERING

PRODUCTION • FABRICATION • TREATMENT • APPLICATION

JANUARY 1941

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THE GROUP of aircraft sand castings shown below illustrates one of the most important DOWMETAL* developments—both as to application and as to method of fabrication.

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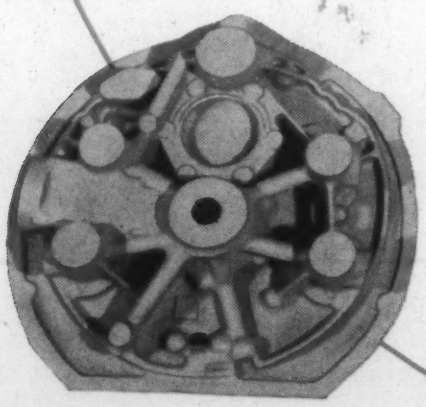

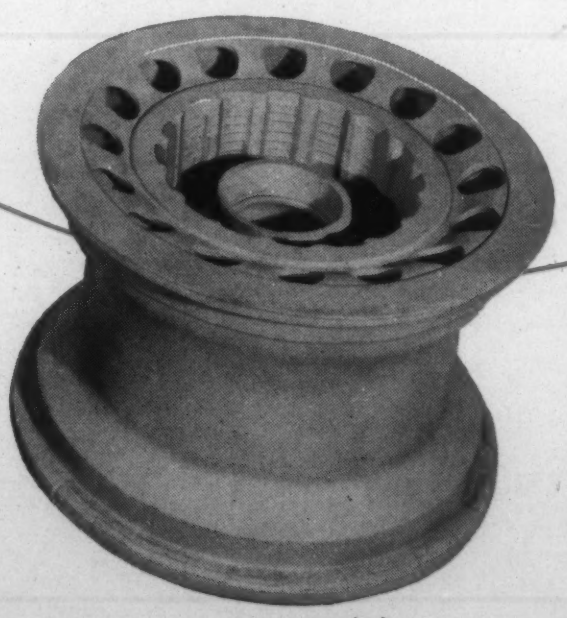

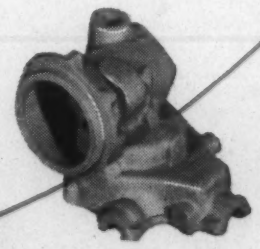

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Metals and Alloys

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Feature Section

Magnesium Alloys in Industry

Because of their lightness, parts made of magnesium alloys find many advantageous uses in many industrial applications. Rather complete information as to their uses in five special fields is given by Mr. Mathes.

Metallography of Stainless Steels

Interpretation of the qualities and the applicability of certain stainless steels depend often on their structure. Mr. Watkins discusses the many practical phases of this complicated subject in the first of a series.

Castings for Heavy Machinery

A pictorial presentation of the application of special iron castings in heavy machinery, with emphasis on the use of "Meehanite," reflects the experience of a large company specializing in modern machine tools and other heavy machinery.

Solid Solutions of Aluminum

In the annealing of alloy sheets coated with pure aluminum, it is important that the pure aluminum coating shall not be contaminated by too extensive diffusion outward of the alloying elements in the core alloy. A knowledge of diffusion coefficients and heat-treating cycles may be devised to avoid this. This discussion of a highly technical subject is authoritative.

Electrical Resistance Furnaces

This article by Mr. Schwarzkopf describes the Stratit heating elements, their cost and operation. It is believed that they open up a new field of application, due to their high temperature range and the possibility of dispensing with a protective atmosphere.

Bessemer Steelmaking

There is currently much ado about the Bessemer process, and with reason. The process can now be accurately controlled to give a more uniform product, economic trends may impel a resurgence of interest in the converter, and metallurgical engineers can now dephosphorize acid Bessemer steels to remarkably low levels, according to a composite digest on page 70.

Engineering Digests

Aluminum Castings

An article in *Foundry Trade J.* (see page 76) tells how to make aluminum alloy castings so they don't resemble porous bearings. Rapid melt-down, avoidance of overheating and immediate pouring seem essential in combatting porosity, but we gather also that a properly-directed prayer should do no harm, either.

Cold-Rolling, Annealing of Strip Steel

German investigations of certain practical factors in producing strip steel are reported in two digests. Lueg & Schultze (page 75) examine the effects of backward and forward pull in cold-rolling, and a composite (page 73) reviews comparative studies of batch annealing and continuous (electric) annealing of cold-rolled steel for deep-drawing.

Welding Aircraft Tubing

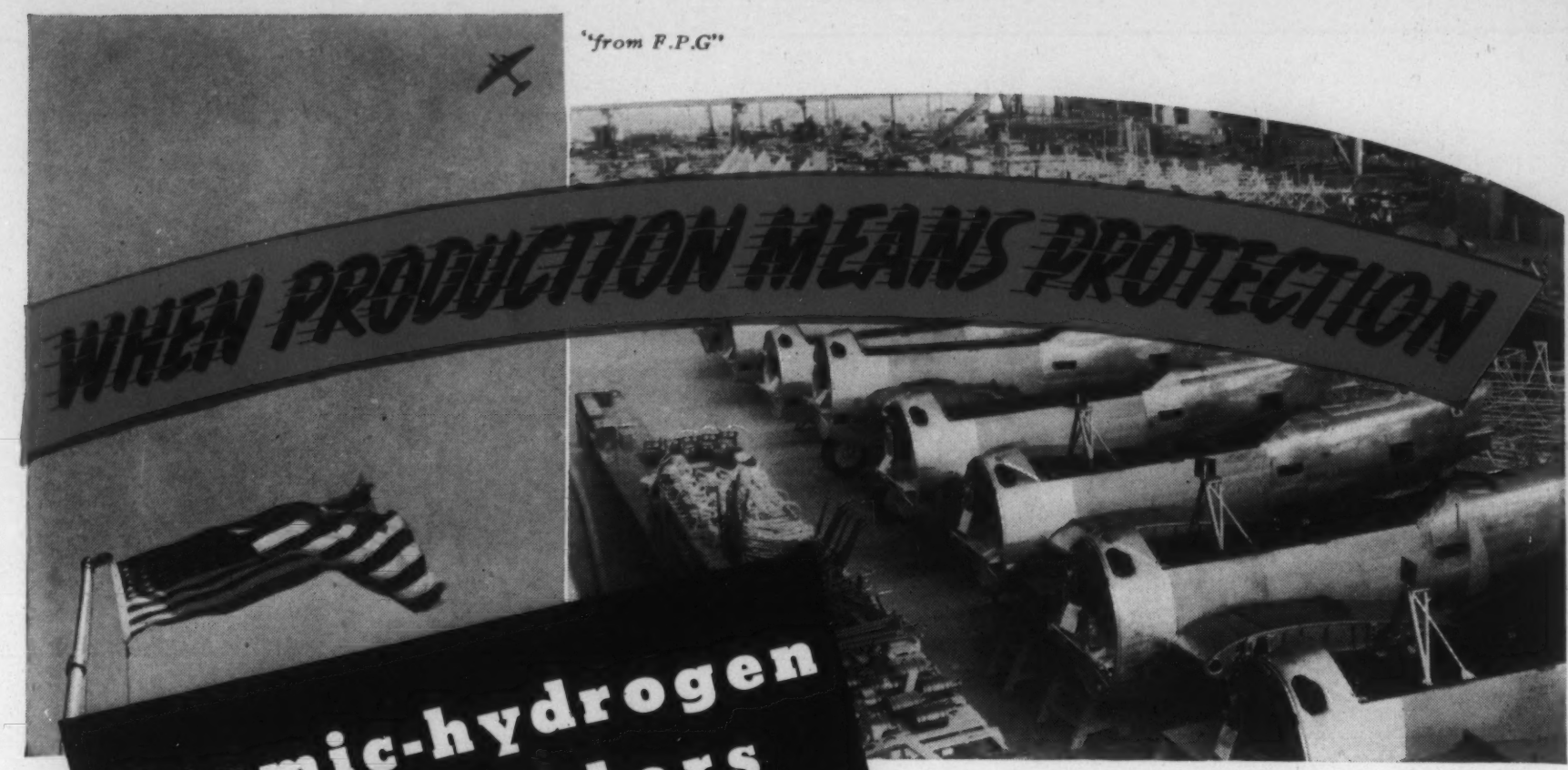
Large quantities of light-walled chrome-moly steel tubing are welded to make light-aircraft fuselages and other components. The use of oxyacetylene welding is facilitated, says Eckman (page 84) by using the "excess acetylene" technique he describes.

High Temperature Design

Whether you're concerned with designing battleship boiler systems, refinery valves or one of a hundred heated-in-service products, the composite on page 96, with its comments on structural stability and on creep vs. rupture in design, should prove helpful.

Lead Cable-Sheath Testing

Service behavior of lead cable sheathing may be as satisfactorily predicted from testing simple tension strips cut from sheathing as from making bursting tests on the sheath itself, say Moore, Dollins & Craig (page 106).



SAVE TIME.. GAIN SPEED

ON REPAIRS

Don't let worn or broken molds, dies, forging hammers, and similar tools sabotage your production. Recondition them quickly by *atomic-hydrogen* arc welding and save practically all the time and expense otherwise required to make new ones. This process is not "patch work"—it restores original contour and wear-resisting qualities of worn tools so well that repairs defy detection.

ON MILD STEEL

Where especially ductile and homogeneous fusion-welded joints are required on mild steel, *atomic hydrogen* does the job better and quicker than any other process. Its precise and accurate control of heat is especially good on thin material in making smooth joints, free from "pin holes" and undercutting.

ON HARD-TO-WELD METALS

In the fabrication of products made of stainless steel, aluminum, chrome-nickel—in fact, any hard-to-weld ferrous or nonferrous alloy—don't waste time in riveting, bolting, or casting until you've tried *atomic hydrogen* to gain the speed of this quality-fusion welding process. The hydrogen gas envelope protects the molten metal and prevents harmful composition changes.

ON HARD-SURFACING

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GENERAL ELECTRIC

672-9

A New Year

We ordinarily let the January issue go by without recognition, in the editorial or the text pages, that it is the first month of the year. A continuous inventory of metallurgical matters, in correlated abstracts and composite digests, seems more useful than the assembling for the January issue of sketchy surveys stating what various authorities consider to be noteworthy progress in the past calendar year plus their guesses for the coming year.

A bit of editorial comment, though not of prophecy, may be in order this January. The conditions of 1941 are so different from normal ones that accurate prognostication is even more impossible than usual. One thing is certain, 1940 was a hell of a year the world over, and 1941 will probably be more of the same. Chaos, brought on by aggressor nations, rules over Europe and Asia, much of which has been over-run and paralyzed by the invaders. The valiant efforts to restore order and to prevent further over-running that are being put forth by England in particular, excite our greatest admiration, and call for our support. Moreover, it has become plain that our own hemisphere is not necessarily immune from attack and that it is necessary to develop our latent ability to exert military force,—the only thing the dictators understand,—into greater strength than they have.

This shifting from a peace time basis to a basis of war and preparedness for war, has entirely rearranged metallurgical activities the world over, since warfare rests upon the production of metals and metal products, and hence upon metallurgical engineering.

Internally, 1940 was also a hell of a year. An administration to which business, *i.e.,* the people who produce things,—is anathema, has been kept in power, and anti-business blatherskites like Ickes are retained therein. This month marks the re-re-inauguration of what may turn out to be the "4th term candidate." This would indeed be a sorry prospect for business in general and metallurgical progress in particular, were it not that the American public grasps the fact that production for preparedness depends on the business and technical ability of those who make things. Producers are not in the public's doghouse. The anti-business zealots of the New Deal may therefore be forced into an unwilling truce. Leopards do not change their spots and polecats require a surgical operation to become odorless. So when the emergency is over, any truce will end.

But during the emergency, metallurgical production and technology will progress. Whether the increase in knowledge on which progress is based will develop along lines of value for future needs as well as for the day-to-day problems, is a matter of importance. The day-to-day problems are on minutiae, for we do not therein utilize brand new ideas and experimental facts; we use those that were brought out in the research and development of 5 or 50 years ago, those that have had time to ripen.

The United States will have to produce a greater proportion of the new fundamental information upon which future progress will be based, than heretofore. Of the countries over-run by the invaders, only France was of much importance in research and development. Her metallurgical journals appear to have ceased publication, nor is it likely that anything is being done worthy of publication. Sweden continues to record important matters in the *Jernkontorets Annaler.* Of the belligerents, England maintains her excellent engineering and metallurgical publications with little decrease in quantity or quality, and is obviously taking thought for the post-emergency conditions that will arise, with a steadfast belief that she can and will outlast and outfight the dictators.

The world used to look to Germany for a goodly proportion of new and basic information, such as appeared in the *Archiv* and the *Mitt. K.W. Institut.* One can hardly appraise the present quality and quantity, because the effective British blockade has kept many of the 1940 issues of these and other German journals piled up in Switzerland, waiting for a chance for shipment. Recently, some of the later issues have come out through Japan and Siberia. Most of these late samples are not very impressive. Only a few of the older authors are publishing and some at least of what they do publish, is picayune, like one report of laborious investigations which showed that the "deformation between the 25th and the 35th hour" in a short time high temperature test gives no useful information as to long-time creep resistance, a matter that the rest of the metallurgical world knew long ago.

It is interesting that despite the war, the abstract sections of both the English and the German periodicals carry résumés of the publications of the other country, showing respect for each other's technical knowledge. Indeed, we learn from the English abstracts something of the subject matter in the German articles in the journal issues held up by the blockade.

Whether there is war or peace, whether the administration is hostile or friendly, the metallurgical industries will develop some new knowledge and

(*Continued on page 51*)

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Magnesium Alloys in Industry

It has been known for a long time that magnesium alloys, because of their lightness, have many advantages. This article gives full information on the industrial applications of certain products made of these alloys where the substitution of lighter weight material is advantageous. Five special fields where this is true are discussed—in manually-handled tools, in certain parts of high-speed machinery, in reducing transportation costs, in lowering machining costs, and in utilizing chemical and physical properties.
—The Editors

by JOHN C. MATHES
The Dow Chemical Co.,
Midland, Mich.

INDUSTRY HAS LONG RECOGNIZED the advantages to be gained from lighter weight in certain processes or applications, particularly those involving manual labor or reciprocating or revolving machinery. With faster production schedules and the higher operating speeds which they require, weight becomes an increasingly significant factor. The easiest, and often the cheapest, means of reducing weight is by utilizing the light alloys which metallurgical development has produced. The lightest of these are the magnesium-base alloys, such as "Dowmetal."

The importance of Dowmetal in applications where weight is an important consideration is illustrated by Table I, which compares its specific gravity with those of other common metals, and by Table II, which gives the physical properties of the most commonly used magnesium alloys. The favorable combination of low weight and high strength which these alloys offer, as well as certain other properties which they possess, make them most applicable for the following purposes:

1. To reduce the weight of manually handled tools.
2. To reduce the weight of reciprocating or revolving parts on high-speed machinery.
3. To reduce transportation costs on items requiring frequent re-shipment.
4. To reduce machining costs.
5. To utilize unique chemical or physical properties.

The following discussion illustrates by specific references these general fields of application.

Reducing the Weight of Manually Handled Tools

Dowmetal castings, plate, and structural shapes have all been used to advantage for manually handled equipment.

Castings were the forerunner in this field because they were the first commercially available form, and because the maximum weight savings can be effected. Magnesium alloy sand castings have physical properties better than ordinary gray iron and equal to other light weight alloys. For this reason, the same pattern equipment used for the heavier metals, with perhaps some slight changes in filleting or ribbing, can be used for the magnesium castings. The volume of metal in the casting, there-

Table I.—Relative Weights of Structural Metals

Material	Specific Gravity	Relative Weight	Weight Lb. per cu. in.	Weight Lb. per cu. ft.
Dowmetal	1.8	1.0	0.065	112
Aluminum Alloys	2.8	1.6	0.101	175
Zinc	7.1	3.9	0.256	443
Cast Iron	7.2	4.0	0.260	450
Tin	7.3	4.1	0.264	456
Steel	7.9	4.4	0.285	493
Brass	8.5	4.7	0.307	531
Bronze	8.8	4.9	0.318	550
Nickel	8.9	4.9	0.322	556
Copper	8.9	4.9	0.322	556
Lead	11.3	6.3	0.408	706

fore, remains practically the same and the full advantage of its lighter weight utilized. Portable tool housings and foundry coreboxes are examples of these maximum weight savings. For both of these, as-cast Dowmetal H has ordinarily been used, since it possesses adequate strength and ductility and avoids the slightly higher cost of heat-treated material.

The reduction in worker's fatigue when the lightest possible tools are used is often reflected in increased plant efficiency. This is an appreciable factor in industries, such as the automotive industry, where grinders, drills, buffers, and power wrenches are handled continuously throughout the working day. Such tools are illustrated in Fig. 1. In other industries, particularly mining, the use of larger drills and tools makes light weight essential.

Coreboxes.—Although not yet in general use, Dowmetal coreboxes, shown in Fig. 2, have proven their efficiency in high production foundries because of four distinct qualities—machinability, rigidity, long service life, and light weight. The ease of machining is a deciding factor, not because the boxes are produced in large quantities, but because of the handwork necessary to completely finish them after the rough and finish cuts are made. In order to obtain the necessary precision, coreboxes are generally trimmed to final shape by hand filing and scraping, processes which are particularly adaptable to

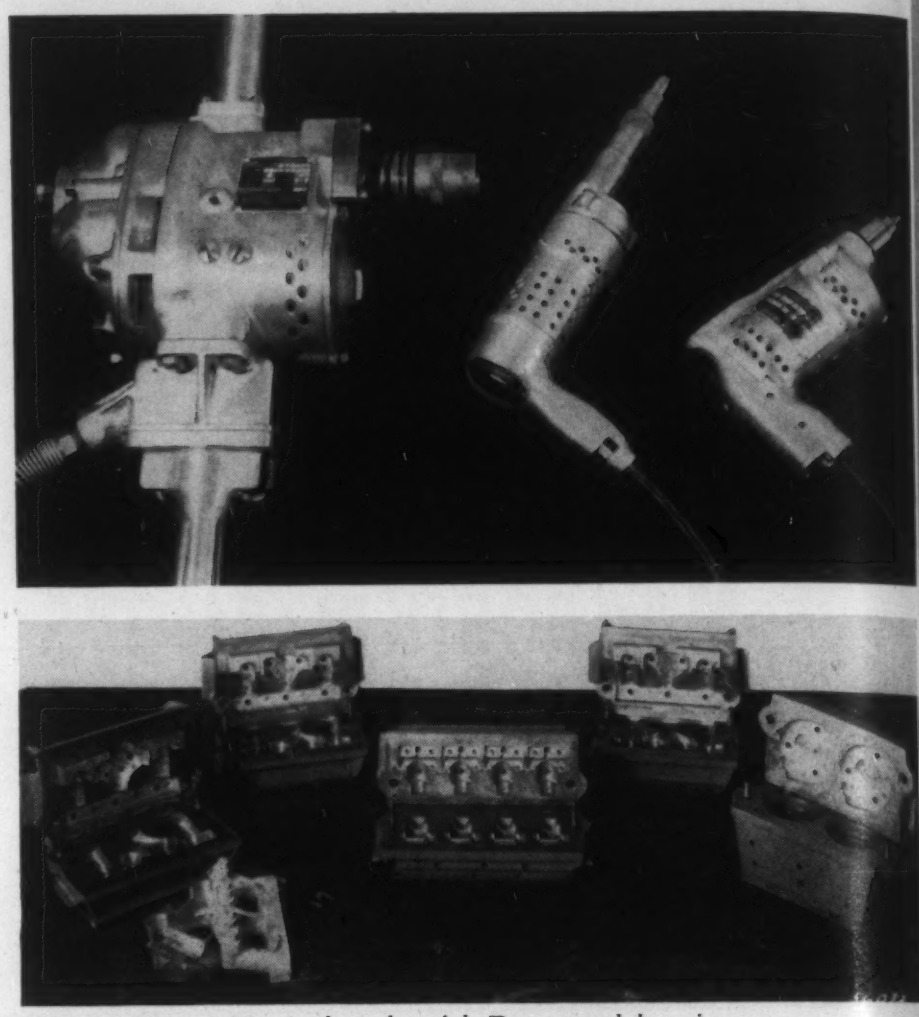


Fig. 1. (Top) Typical tools with Dowmetal housings.
Fig. 2. (Bottom) Dowmetal core boxes.

Table II.—Composition, Typical Mechanical Properties, and Uses of Magnesium Alloys

Designation (*a*) Dowmetal Alloy	A.S.T.M.	Nominal Composition (*b*) Al	Mn	Other	Form and Condition	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., per cent	Brinell Hardness	Endurance Limit, lb. per sq. in.	Characteristics and Uses
E	No. 7	6.0	0.2	.....	Sheet, hard rolled	45,000	34,000	9	70	.....	General applications requiring high strength.
					Sheet, annealed	39,000	20,000	15	57	.....	General applications requiring formability.
H	No. 4	6.0	0.2	3.0 Zn	As sand cast	27,000	12,000	5	53	10,000	Sand castings requiring good properties and resistance to salt water.
					Heat-treated	38,000	12,000	11	53	10,000	
					Heat-treated & aged	38,000	18,000	5	70	10,000	
J (*c*)	No. 8	6.5	0.2	0.7 Zn	Extruded	43,000	30,000	17	54	17,000	Extruded shapes of improved strengths.
					Forged	40,000	24,000	10	57	17,000	Good forgeability; medium-stressed parts.
L	.....	2.5	0.3	3.5 Cd	Hammer forged	37,000	26,000	11	51	.....	General hammer forging requirements.
M	No. 11	..	1.5	.....	Sheet, hard rolled	35,000	27,000	9	53	.....	Moderately-stressed applications requiring maximum resistance to salt water, and good weldability.
					Sheet, annealed	33,000	19,000	14	48	.....	
					Extruded	42,000	27,000	6	42	6,000	
					Forged	33,000	19,000	6	43	.....	
O (*c*)	No. 9	8.5	0.2	0.5 Zn	Extruded	47,000	33,000	11	61	17,000	Highly-stressed parts of simple design.
					Forged and aged	46,000	33,000	6	82	.....	
P	No. 14	10.0	0.1	1.0 Zn	Sand cast, heat-treated and aged	36,000	22,000	1	77	8,000	Castings requiring highest yield strength and hardness and not subject to shock.
R	No. 13	9.0	0.1	0.6 Zn	Die cast	33,000	21,000	3	60	.....	Standard die casting alloy. Good casting characteristics and high properties.
X (*c*)	No. 15	3.0	0.2	3.0 Zn	Extruded	42,000	30,000	19	51	18,000	Extruded sections and forgings with best combination of properties and resistance to salt water.
					Extruded and aged	44,000	34,000	13	54	17,000	
					Forged and aged	42,000	28,000	14	62	.....	

(*a*) Most of the compositions listed conform to American Society for Testing Materials (A.S.T.M.), U. S. Navy's Bureau of Aeronautics, and Army Air Corps specifications for magnesium alloys.

(*b*) Magnesium is the balance in each alloy.
(*c*) Compositions with 0.005% max. iron and 0.005% max. nickel of improved resistance to salt water are designated J-1, O-1 and X-1.

Dowmetal. Rigidity is also essential, and it has been found that Dowmetal boxes, made to the same standards as boxes of heavier metals, meet this requirement.

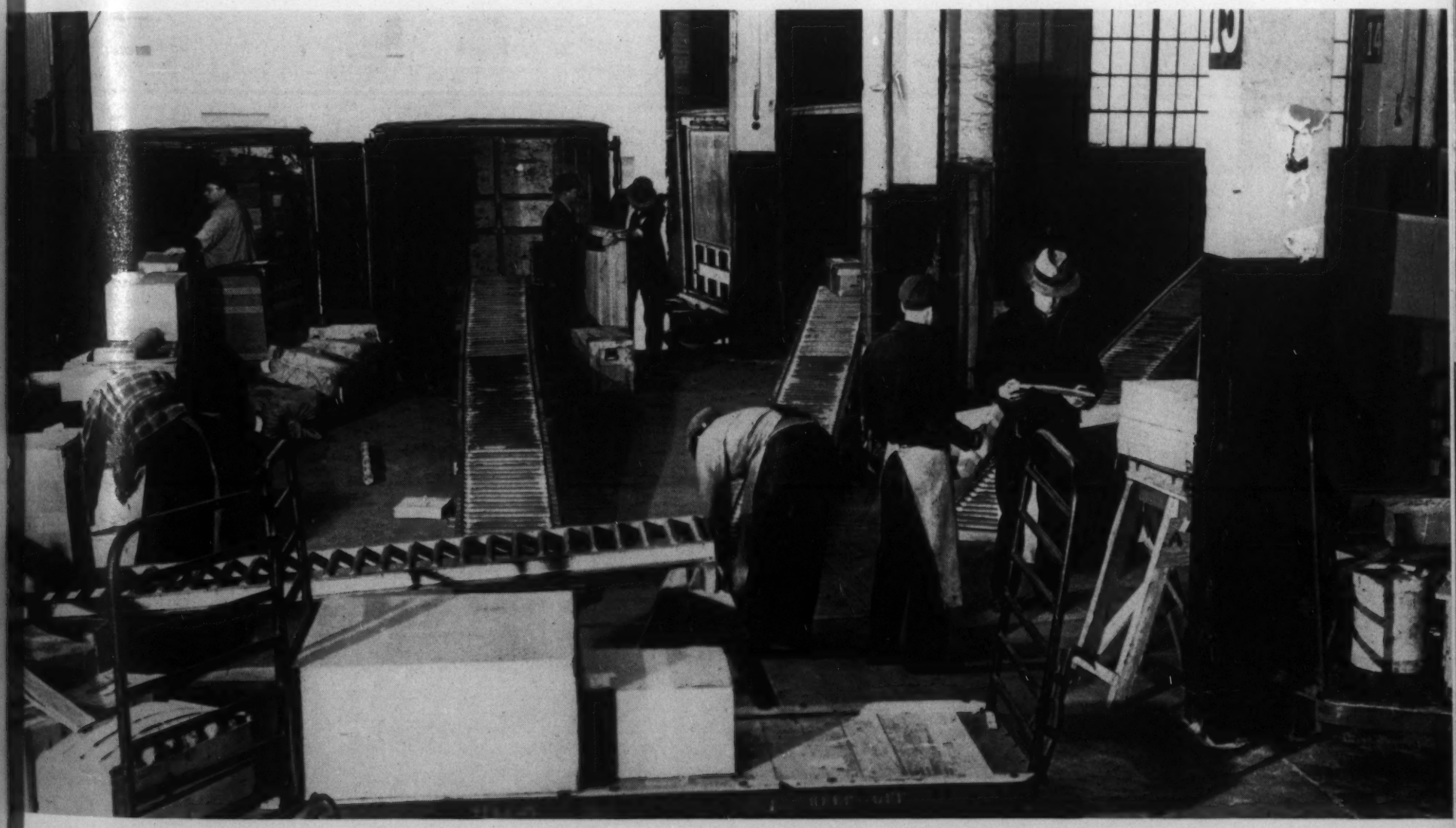
Service records from a hand-rammed, 5-piece core box used for 63,000 sets of cores up to a high production gang core box used for 3,674,000 sets of cores do not show that such boxes have distorted though subjected to the rough handling which goes with high production. Even though magnesium is considerably softer than most of the other metals used, it has been found that coreboxes made of it require no additional expense for upkeep. Similar to standard practice for boxes of other metals, the parting lines, projecting bosses and other locations subject to excessive erosive action are steel faced. The fast-wearing areas where sand particles from a blowing machine enter the box are also recessed and faced with hardened steel in some cases. More often, however, they are allowed to wear to some extent and are then built up with hard solder and hand scraped to the correct profile. Magnesium lends itself readily to this practice.

These boxes are, of course, much lighter than if made of any other metal, as coreboxes of the next lightest metal are approximately 50 per cent heavier and steel or iron coreboxes would be over 300 per cent heavier. The value of this reduced weight is shown by the records of one plant where the production was increased 14 per cent by replacing steel with magnesium coreboxes.

In addition to coreboxes, Dowmetal pattern plate and foundry flasks are also widely used in foundries where their lighter weight contributes to easier and more efficient operation. Pattern plates are generally made of rolled Dowmetal E and are at least 25 per cent lighter than plates of equal rigidity made of any other material. This is particularly important for the quantity production or accurate work associated with mounted patterns.

Structural Shapes.—Portability is also an important consideration in many industrial operations and, as a result, there is a definite advantage in constructing certain types of equipment from Dowmetal structural shapes. When subjected to bending stresses, the strength and stiffness of structural members increase approximately as the square and the cube of the depth respectively. It is thus possible, by slightly

Fig. 3. Installation of Dowmetal gravity conveyors.



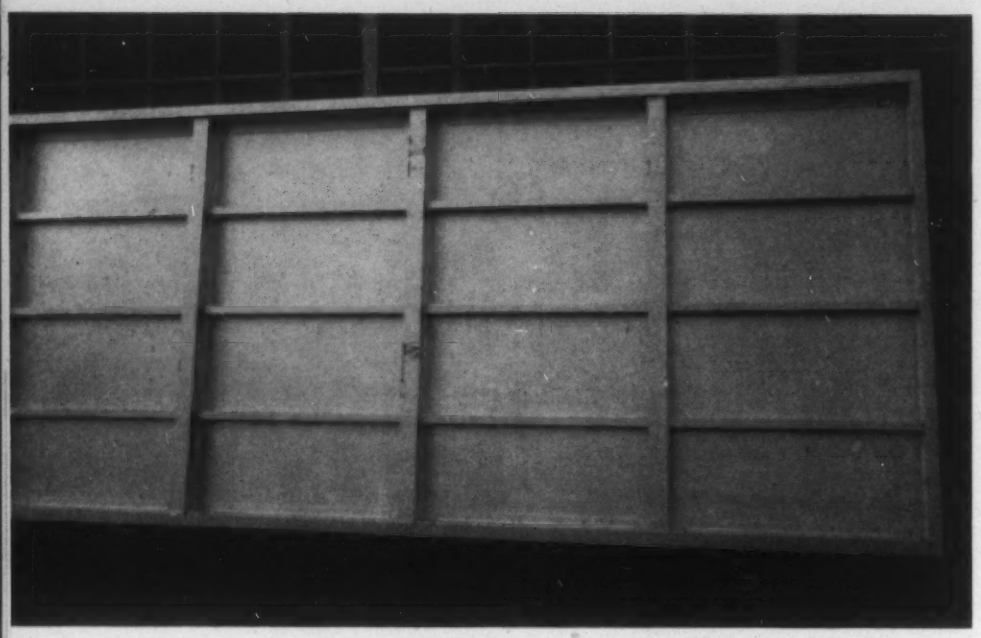
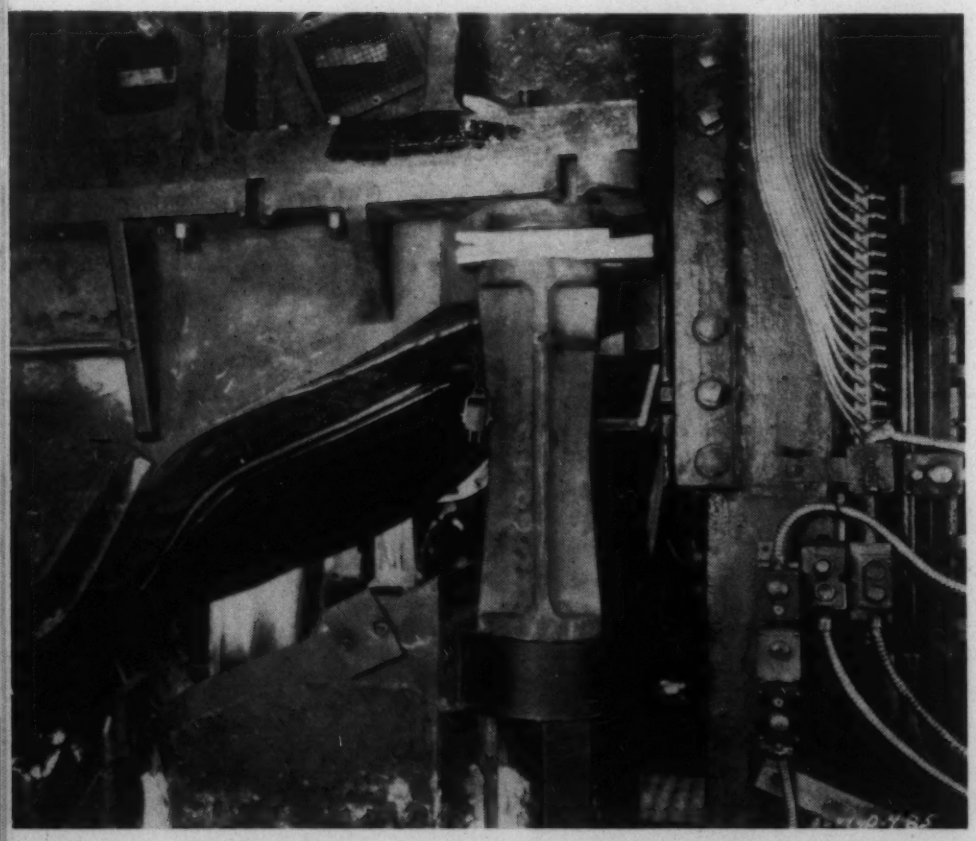


Fig. 4. Dowmetal dockboard.

increasing the depth of the structural sections, to replace heavier materials with magnesium alloys, securing equivalent or increased strength and stiffness and retaining very important saving in weight.

This is illustrated by the Dowmetal gravity conveyor sections used at many railway express terminals. The weight of these conveyors was reduced from 160 lbs. in steel to 70 lbs. in Dowmetal, of which approximately 20 lbs. represent the weight of the steel roller bearings. Dowmetal X channels of a slightly greater depth than the steel were used for the main side members. The bracing angles and tubular rollers are also made of this alloy with the

Fig. 6. Cast Dowmetal safety block installation.



latter being aged to obtain maximum hardness. To date, approximately 20,000 ft. of these conveyors have been installed in various terminals, and it has been found that the ease of handling these lighter sections has so greatly increased the efficiency that they have paid for themselves in a comparatively short time. A typical installation is shown in Fig. 3.

Besides contributing to increased efficiency, Dowmetal has also contributed to better safety records in many plants through the use of dockboards, safety tongs or safety blocks made of these alloys.

Dockboards.—Dockboards for loading or unloading freight cars have generally been made of steel or wood. Such boards may range from small sizes to accommodate hand trucks to large boards capable

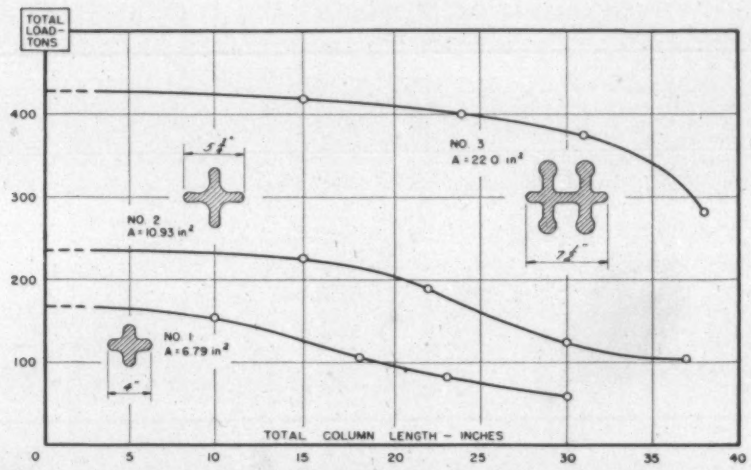


Fig. 5. Test curves showing ultimate strength of extruded Dowmetal safety block sections for various lengths.

of carrying heavily loaded electric trucks and trailers. These boards are often too heavy and unwieldy to be readily handled by one or even by two men. To avoid the necessity of calling extra men from their work in order to set the boards in place, there is a definite advantage in constructing them as light as possible. As a result, Dowmetal has been used rather widely for this purpose for the construction of dockboards of all sizes.

Besides reducing the man-power necessary for handling them, the possibility of personal injury is greatly reduced as there is less chance that the board will be inadvertently dropped while being carried. In one of the large motor plants, for example, steel boards weighing 625 lbs. were replaced by Dowmetal boards weighing but 200 lbs. each. In another plant, it was necessary to install a removable bridge for loading cars on a track a considerable distance from the dock. As designed in Dowmetal, this 14 by 6-ft. platform weighed but 390 lbs. and is illustrated in Fig. 4.

Safety Tongs and Blocks.—Safety tongs for feeding blanks to stamping presses are universally used to protect the worker's hand and are made of many ma-

terials. Cast Dowmetal H tongs reduce workmen's fatigue because of their lightness and have the further advantage of preventing injury to the dies in event that the die is closed upon them. Safety blocks, also used in conjunction with stamping presses, have long been an additional precaution to hold the press open while men were working on the dies. Until a few years ago, green oak or steel were commonly employed for such blocks. However, their weight and size made them difficult to handle and tended to discourage their use by the workmen even when they were made available at the presses.

Also, oak blocks in the common sizes were not strong enough to withstand the loads in medium or large sized presses should they be accidentally tripped. A fatal accident in one of the large plants focused attention on this problem and, to prevent recurrences, their safety engineers cooperated with The Dow Chemical Co. in developing a cast Dowmetal safety block considerably stronger than oak and lighter and easier to handle than either oak or steel. These safety blocks were made of heat-treated Dowmetal H castings and were found to give highly satisfactory service in a large number of plants for several years. However, the expense of making new patterns for each size or length restricted an even wider use. To meet the situation, and to lower costs through standardization, extruded Dowmetal X alloy blocks were developed and tested. These extruded sections can readily be cut into any desired length and are lighter and stronger than the cast blocks. Fig. 5 illustrates the sections and load capacity of these extruded blocks and Fig. 6 illustrates a typical cast safety block installation.

Fig. 7. Typical Dowmetal die castings.

Reducing the Weight of Parts in High Speed Machinery

Besides contributing to the safer and more economical use of manually handled equipment, magnesium alloys have also been utilized to increase the efficiency of high speed machinery. A typical case is the substitution of Dowmetal for bronze in a centrifuge head operating at speeds up to 5,000 r.p.m. As-cast Dowmetal H for this head reduced its weight from 51 to 21 lbs. This had the immediate effect of reducing starting inertia and obtaining quicker

maximum speeds and also effected less wear on the thrust bearings, an easier handling of the heads, and a reduction in manufacturing costs. On a special vacuum pump, Dowmetal eccentric cams in the place of cast iron brought the weight from 9-1/4 to 2-2/3 lbs. The lighter cams greatly lessened vibration with a consequent increase in performance and longer equipment life.

On larger and more massive equipment, Dowmetal has also been employed to advantage, as on an automatic machine requiring accurate indexing. The original installation on this machine included a revolving cast iron head and, due to inertia, great difficulty was experienced in keeping the indexing mechanism properly adjusted. By substituting a cast Dowmetal head which was 350 lbs. lighter, this trouble was overcome and the output of the machine increased by 100 operations per hour, an increase of 12-1/2 percent.

Perhaps the most extensive use of Dowmetal in revolving mechanisms has been for the hubs and blades of large axial flow fans in the cooling towers of air-conditioning systems. Its light weight is here directly evaluated in increased efficiency, substantially lower power costs, and the elimination of such equipment as heavy drive chains and electric starting devices. These fans have been made of as-cast Dowmetal H in sizes up to as large as 13 ft. in diameter and 900 lbs. in weight for the hub and blade assembly.

Other types of equipment in which the lighter weight of magnesium has contributed to more economical operations include packaging machinery, automatic glass working machinery, knitting and weaving machines, and, in the rayon industry, for bobbins and warp beams. Die castings and extrusions as well as sand castings have been incorporated in equipment of this type. Some of these parts are included among the Dowmetal die castings shown in Fig. 7.

Light Weight Saves in Transportation

The use of magnesium alloys for bobbins and spools for shipping yarn and wire is an outstanding example of the utilization of Dowmetal to save weight in transportation. In most cases such merchandise is shipped to the weaving mills on returnable spools which are re-shipped several times each year. Wooden spools are commonly used but they have the disadvantage of becoming easily broken, warped out of shape, or otherwise rendered unusable.

Because of their light weight, magnesium alloys are particularly suitable for the metal spools which increasingly are being substituted for the wooden spools.

In the printing and engraving industry, Dowmetal engraving plates also serve to reduce shipping cost. Particularly as compared to brass, this is an appreciable factor because it is so often necessary to deliver the plates by special delivery or air mail.

Table III.—Relative Machinability of Metals
(Horsepower Per Cubic Inch of Metal Removed per Minute)

Material	Operation		
	Planing	Drilling	Milling
Dowmetal	1.00	1.00	1.00
Bearing bronze (70Cu-25Pb-5Sn)	1.51	1.20	1.36
No. 12 Aluminum alloy	2.21	1.69	1.57
No. 31 Aluminum alloy	2.58	2.21	1.56
Yellow brass (70Cu-27Zn-2Pb-1Sn)	2.22	2.02	2.58
Brass screw stock	2.26	1.76	2.10
Cast iron	4.08	3.41	3.05
S.A.E. 1112	5.89	4.91	6.13
Steel screw stock	7.03	5.45	5.36
S.A.E. 1020	6.88	6.50	5.83
Copper annealed	7.49	10.00	5.49
Nickel "A"	12.35	13.00	9.06
Monel metal	13.32	8.20	8.72

Reducing Machining Costs

It has been found that production costs frequently are lowered by the use of Dowmetal parts due to the remarkable machinability of magnesium, which is generally considered to be better than that of any other common metal. Experience in the average machine shop has proven that practically all machine tools can be run at their maximum speeds and with feeds at the full capacity of the machine. Cuts as heavy as 1/2 in. at feeds of 20 ft. per min. down to lighter cuts at 700 ft. per min. are being used for turning these alloys. This characteristic, with its attendant lowering in power requirements and costs, is illustrated by Table III which is based largely on work done by O. W. Boston (*Trans.* Amer. Soc. Steel Treating, Vol. 16, 1929, pp. 678-679).

Such excellent machinability contributes to a lower overall cost of completely finished castings, or other parts, generally; but it is particularly true in the engraving industry where the cost of machining or routing may be the major cost of the job. As previously mentioned, the easy machinability of Dowmetal has led to a wide use for printing plates, and rolled Dowmetal E, because it possesses maximum strength and hardness, is generally specified.

Brass was formerly used almost exclusively because of its machinability but in some cases machining costs have been reduced as much as 30 per cent by substituting Dowmetal. Although rubber printing dies are generally made from the engraved plates, the latter are sometimes used directly for printing, particularly on bags, boxes, or cartons. For such service magnesium alloys have a much longer life than ordinary type metal.

Besides substituting Dowmetal for brass engraving plate, many plants have replaced zinc backing plates on rubber dies with Dowmetal backing plates for the following reasons:

a. To increase the ease of handling.
b. To reduce the possibility of damage if dropped.
c. To reduce the transportation cost on rush shipments.

Utilizing Unique Chemical or Physical Properties

The purely chemical uses of magnesium as an essential constituent in zinc and aluminum alloys, as deoxidizer for non-ferrous alloys, as powder for military pyrotechnics, and as shavings in organic synthesis by the Grignard Reaction are generally known. It should be noted that commercially pure magnesium and not alloy, is used for the applications just mentioned.

In an earlier paper in METALS AND ALLOYS Mr. Robert T. Wood (February, 1940) discussed magnesium for photoengraving work and in detail described why its chemical and physical properties make it eminently suitable for this process. The conclusions of this article were:

1. Magnesium plates can be processed by all three commonly employed light-sensitive tops.
2. Magnesium plates are suitable for line-cuts, coarse screen or fine screen work, and thus capable of replacing both copper and zinc, allowing the plant to standardize on one plate material and one processing method.
3. Magnesium plates can be processed more rapidly than either copper or zinc plates.
4. Magnesium plates allow longer runs when used for direct printing.
5. Magnesium plates will make more and better mattes.
6. Magnesium plates weigh less than one-fourth as much as zinc plates and less than one-fifth as much as copper plates which results in greatly lowered mailing cost to firms that ship plates long distances.

Although the author has pointed out that the above process is still experimental and that more work remains to be done before magnesium is marketed for this purpose generally, it serves as a pertinent illustration of an application utilizing its unique chemical properties.

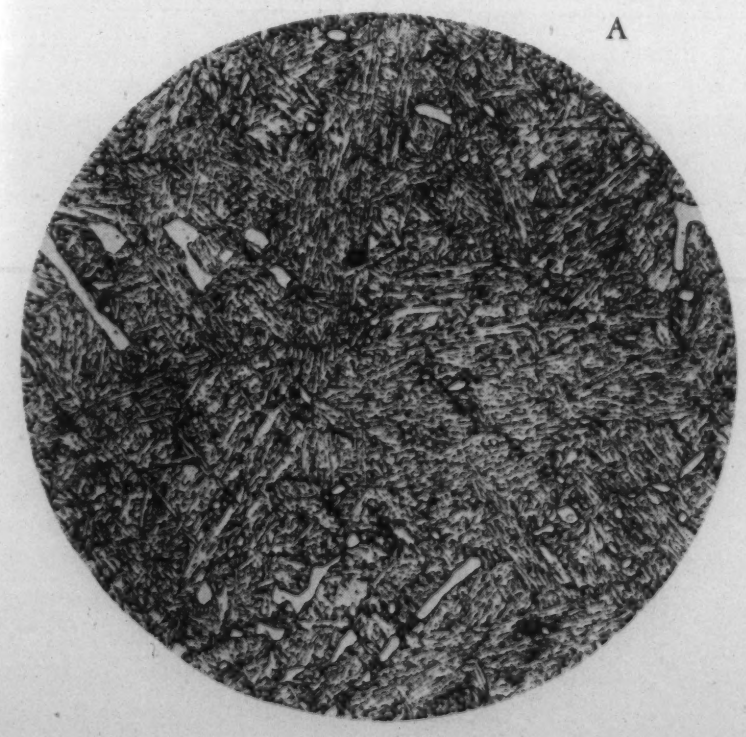
Of a different nature, the electrical and casting properties of magnesium are utilized to advantage in the pressure die casting of rotors for electric motors. The general advantages of die casting rotors are not only that the process produces sounder and more uniform rotors, but it also permits changes in shape and cross sectional area which would be impracticable with rod or wire of fixed commercial standard gages. Aluminum and magnesium alloys are both used for this purpose and the electrical properties of the latter are such that they are particularly suited for high torque rotors.

Some of the various ways in which magnesium alloys have been utilized to advantage in industrial work have been mentioned and many others exist. Designers and metallurgists, in their constant search to find better materials and better ways of accomplishing desired results, are developing an ever-increasing field of applications for these alloys. New alloys constantly are being developed which, in turn, open new fields of application. This condition has led to an exceedingly rapid growth of the use of magnesium alloys in the short 20 years since they were first commercially produced in this country.

Correction—Addenda—*In the article—"Properties and Heat Treatment of 9 Per Cent Cr—1.5 Per Cent Mo Cast Steels"—in our November, 1940, issue, pages 615 to 619, two photomicrographs were unavoidably omitted. They are referred to in the next to the last paragraph at the end of the table on page 619, and in the table of data following that paragraph.*

To further round out the discussion and complete the data, they are reproduced herewith.

A



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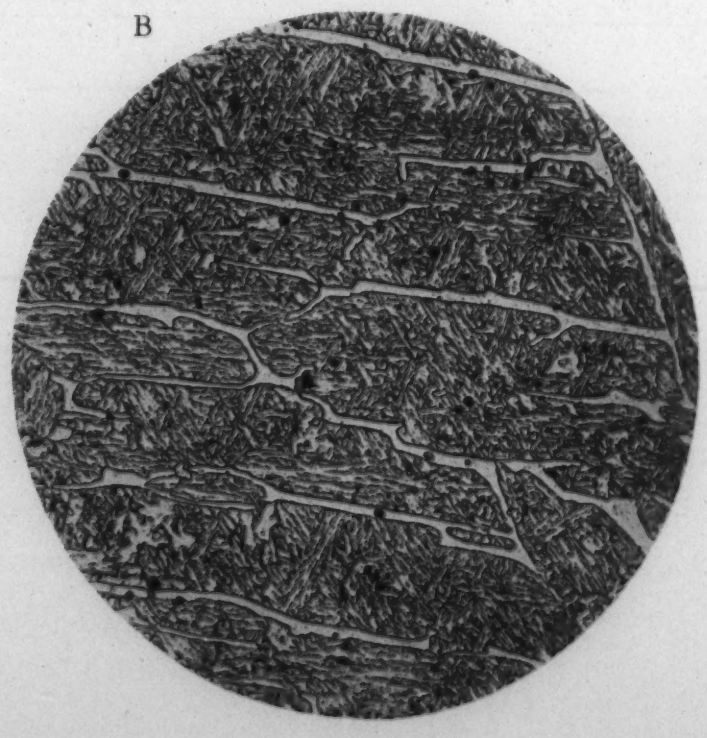


Practical Metallography of the

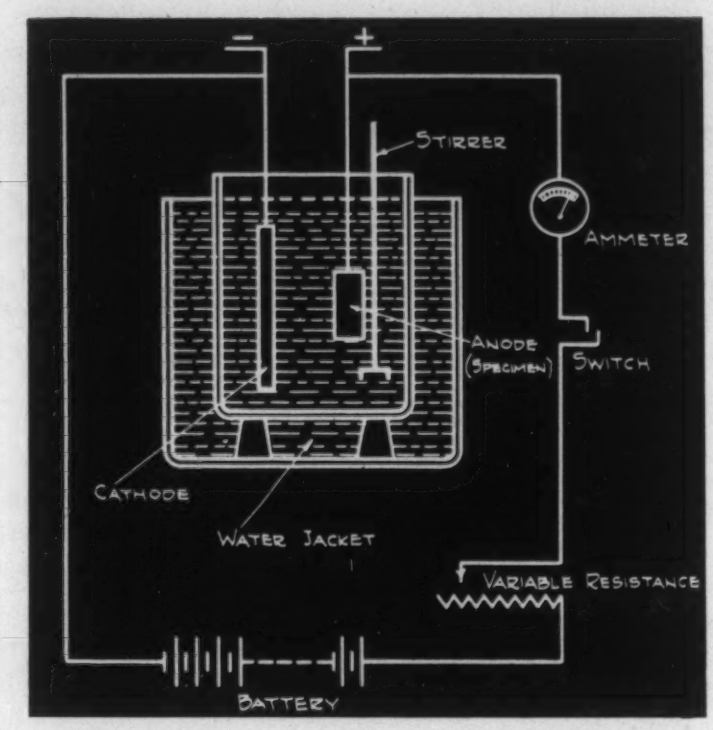


Fig. 1. Diagram of apparatus for electrolytic polishing the stainless steels. (Courtesy: International Tin Research and Development Council.)

The metallography of the stainless steels is very complicated, due largely to the many variations in composition and to the effects of heat treatment on these. Etching and polishing are important factors in the successful examinations of these steels and in their interpretation.

Connected as the author is with a company that makes only these steels, his experience in this field has been broad and he discusses the subject in its many phases in a practical and authoritative manner. —The Editors.

THE AIM OF THE METALLOGRAPHIST is to reveal, identify and interpret the structural constituents of metals and alloys. To accomplish this it is necessary to produce a highly polished surface, and to etch this surface, selectively, with the proper reagent so that the chemically or physically distinct parts may be rendered visually apparent and distinguishable to the greatest degree. Etching is used to produce in one way or another an increased optical contrast between the various structural components, since the polished surface of a metal will usually show no trace of its metallic structure, all incident light being reflected in the same way over the whole of the polished area. The requisite optical contrast is made possible by selective attack, or selective coloring, of the polished surface of the specimen, and is due to varying degrees of resistance to the chemical action of the etching reagent possessed by the various constituents.

The host of new ferrous alloys developed within recent years had compelled the metallographist to employ new methods and reagents for developing their structures. The proper etching of the iron-chromium and iron-chromium-nickel alloys, commonly known as stainless steels, is a difficult task, and the utmost in technique and ingenuity is necessary if satisfactory results are to be obtained.

Numerous methods have been proposed for polishing stainless steel specimens for microscopic examination and most of them produce satisfactory results when properly carried out. Several types of automatic polishing machines are available which are reported to produce good results and serve to eliminate a great deal of drudgery associated with hand polishing. However, perfectly acceptable specimens can be prepared by hand grinding on emery paper, followed by wet polishing on horizontal wheels covered with broadcloth impregnated with levigated alumina or jeweler's rouge. The principal precautions to observe when polishing the stainless steels is to prevent surface distortion by cold working and the formation of polishing pits. The best results are obtained when just sufficient grinding or polishing is done at each operation to remove the effects of the previous operation. In many cases, etching lightly and repolishing on the final broadcloth wheel

e Stainless Steels–I

by STANLEY P. WATKINS

Manager, Development Division,
Rustless Iron and Steel Corp.
Baltimore, Md.

is helpful in minimizing effects of surface distortion occurring during polishing operations.

Electrolytic Polishing

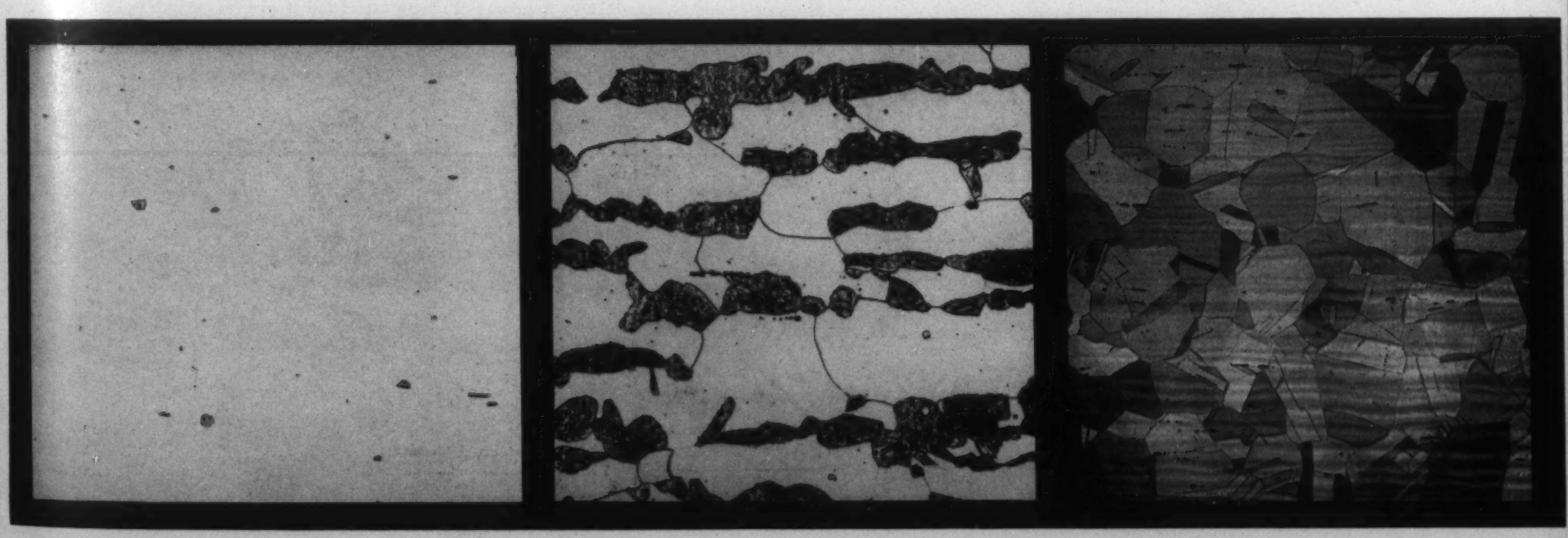
The conventional method for preparing metallographic specimens, involving as it does grinding and polishing, has disadvantages because even the mildest form of mechanical polishing alters to some extent the original character of the surface metal. In order to overcome this condition, an electrolytic polishing process has been developed which is reported to avoid any mechanical work and yields smooth surfaces, particularly suitable for microscopical examination and having a higher reflectivity than is commonly produced by grinding and polishing. A diagram of an apparatus suitable for electrolytic polishing is shown by Fig. 1.

The solution recommended for electrolytic polishing the "18 and 8" type stainless steels consists of 765 c.c. acetic anhydride, 185 c.c. perchloric acid (d.-1.61) and 50 c.c. water. In preparing this solution, the anhydride should be poured very slowly into the well cooled perchloric acid and the water added last. The solution should be allowed to stand about 24 hrs. before using. For polishing, the current density should be at least 10 amps per sq. dm. and voltage between 50 and 60. In addition the solution should be maintained at a temperature below 30 deg. C. If the surface is fairly smooth, polishing is effected in about 5 mins. During electrolysis a viscous reddish-brown substance forms on the specimen which can be removed by washing in water and alcohol. Perchloric acid reacts violently with organic substances and care should be exercised in handling this acid.

The examination of a well polished sample of stainless steel will show the number and distribution of non-metallic particles (Fig. 2), but will reveal nothing of its metallic structure. In order to produce a contrast between its various constituents, it is necessary to use etching reagents. Etching effects an optical contrast between the different constituents by selective attack or selective coloring, which is primarily due to varying degrees of resistance to chemical action possessed by the constituents present. The stainless steels are inherently highly resistant to chemical attack and for this reason the comparatively weak etching reagents used for developing the structures of ordinary steels are not generally suitable.

When a stainless steel alloy contains more than

Fig. 2. (Left) Unetched structure of 18 and 8 stainless steel. Mag. 200X. Fig. 3. (Center) Etched structure of 17 per cent Cr stainless steel. Martensite, the dark constituent, is less resistant to etchant than ferrite matrix. Etchant: 10% HCl in alcohol, electrolytic. Mag. 200X. Fig. 4. (Right) Etched structure of annealed 18 and 8 stainless steel. Etchant: HCl-copper sulphate. Mag. 100X.



one phase, the various phases are generally attacked with different intensities (Fig. 3). The more strongly attacked areas usually become roughened and, therefore, appear darker when viewed under vertical illumination.

On the other hand, when an alloy consists of only one phase the various crystals will, after etching, usually appear to be of different degrees of brightness (Fig. 4). This is often referred to as the "oriented lustre" of metals, and is due primarily to a difference in shape and orientation from one crystal to another.

In general, the etching reagents used in the metallographic study of stainless steels are dissolved in water, glycerine, ethyl or methyl alcohol, or in mixtures of these liquids. Since the methods used in etching these alloys are based solely upon chemical action it is important that the polished surfaces be "wetted." An aqueous solution wets a metallic surface much more unevenly than solutions in alcohol, which is primarily due to the latter's property of readily dissolving grease. Therefore, it is easier to obtain uniform etching with alcoholic solutions. In addition, solutions in alcohol have another advantage in that, due to their lower dissociation, they can be made considerably more concentrated than aqueous solutions without becoming too powerful in their action. In this respect, solutions in glycerine act similar to those in alcohol.

Reagents for Immersion Etching

In the etching of stainless steels for microscopic examination, it should be borne in mind that they readily become passive, and that in general a reducing condition rather than an oxidizing one, which favors passivity, should be maintained during etching. For this reason most of the reagents for etching these alloys contain hydrochloric, hydrofluoric or sulphuric acids. However, nitric acid is often used alone or mixed with hydrochloric acid to form aqua regia. The method in general used for etching stainless

Table I.—Reagents used in the Immersion Etching of Stainless Steels for Microscopic Examination

Reagent	*Composition*	*Remarks*	*Recommended Use*
1 "Aqua regia glycerol"	1 part nitric acid 2 parts hydrochloric acid 3 parts glycerol	Use freshly prepared. Warm specimen in hot water before etching. Etching time 3 to 10 secs. Proposed by Vilella.	Structures of iron-chromium and iron-chromium-nickel alloys.
2	2 parts hydrofluoric acid 1 part nitric acid 2 to 4 parts glycerol	Amount of glycerol may be varied to suit metal. Proposed by Vilella.	Structures of the high-silicon alloys of the duriron type.
3	1 part nitric acid 2 parts hydrochloric acid 2 parts glycerol 1 hydrogen peroxide	Proposed by Vilella	For etching the austenitic stainless steels
4	Saturated solution of ferric chloride in HCl, to which a few drops of nitric acid are added	Use full strength	Structures of all types of stainless steels
5	4 gm. copper sulphate 20 ml. HCl 20 ml. water	Proposed by Marble	Structures of all types of stainless steels
6 "Chrome regia"	25 parts HCl 5 to 50 parts of 10% chromic acid	Activity is controlled by amount of chromic acid. Proposed by Newell.	Heat treated austenitic stainless steels
7 Aqua regia	1 part nitric acid 3 parts hydrochloric acid	Reagent should stand 24 hrs. before using. Use full strength for rapid work, but requires careful handling.	Structures of all types of stainless steels
8	5 gms. ferric chloride 50 ml. hydrochloric acid 100 ml. water	Use full strength. Apply with piece of cotton and swab gently.	Structures of austenitic stainless steels
9	10 ml. hydrochloric acid 90 ml. water	Use boiling	Structures of all types of stainless steels
10	100 ml. hydrochloric acid 100 ml. water 7 gms. mercurous nitrate	Use full strength	Structures of all types of stainless steels
11	20 ml. hydrochloric acid 20 ml. water 4 gms. copper sulphate	Use cold	Useful for determining orientation of grain boundaries
12 "Murakami"	10 gm. potassium ferri-cyanide 10 gm. potassium hydroxide 100 ml. water	Use freshly prepared boiling solution. Etching time is 15 secs. to 3 mins. Proposed by Murakami.	Reveals free carbides in the stainless steels
13	4 gms. potassium permanganate 1 gm. sodium hydroxide 100 ml. water	Use just under boiling point. Etching time 1 min. Proposed by Groesbeck.	Reveals free carbides in the stainless steels.
14	5 ml. hydrochloric acid 1 gm. picric acid 100 ml. ethyl alcohol	Proposed by Vilella	Martensitic and ferritic stainless steels

Table II.—Reagents used in the Electrolytic Etching of Stainless Steels for Microscopic Examination

Reagent	*Composition*	*Remarks*	*Recommended Use*
1	20 ml. perchloric acid (70%) 80 ml. water	Etching time 20 secs. to 2 mins. Proposed by Watkins	Austenitic stainless steels
2	10 ml. hydrochloric acid 90 ml. methyl alcohol	Etching time 10 to 30 secs. Proposed by Merritt	Martensitic and ferritic stainless steels
3 "Lactol"	5 ml. hydrochloric acid 50 ml. methyl alcohol 50 ml. lactic acid	Etching time 10 to 30 secs. Proposed by Wyche	Martensitic and ferritic stainless steels
4	Conc. nitric acid	Etching time 1 to 5 secs. Action is extremely rapid	Austenitic stainless steels
5	10 gms. oxalic acid 90 ml. water	Etching time 30 secs. to 3 mins.	Austenitic stainless steels
6	1 part "chrome regia" 2 parts alcohol 2 parts glycerol	Etching time 20 secs. to 1 min.	Austenitic stainless steels
7	10 gms. sodium cyanide (less than 0.20% Cl) 90 ml. water	Carbides revealed after 1 to 5 mins. Etching at 0.5 to 1.0 amp. and 6 volts. Proposed by Groesbeck.	Free carbides in all types of stainless steels
8	10 gms. ferric oxalate 90 ml. water	Etching time 2 mins., at 0.1 amp. and 60 volts	Free carbides in all types of stainless steels
9	10 gms. potassium ferri-cyanide 90 ml. water	Etching time 2 mins., at 0.50 amps. and 6 volts	Free carbides in all types of stainless steels
10	10 gms. tartaric acid 90 ml. water	Etching time 5 mins., at 0.10 amp. and 6 volts	Free carbides in all types of stainless steels
11	10 gms. chromic acid 100 ml. water	Etching time 15 to 20 secs. at 0.50 amps. and 6 volts	Free carbides in all types of stainless steels. Prolonged etching reveals structure.

steel specimens for microscopic examination is to wet the polished surface with alcohol and immerse in the etching reagent for a definite period. Oftentimes it may be advisable to lightly swab the surface of the specimen with a wad of cotton to effect a more uniform attack. However, due to the passivity of polished stainless steel surfaces, immersion etching of these alloys is not generally as satisfactory as electrolytic methods. Table I lists the more common reagents used in the immersion etching of the stainless steels.

The electrolytic method for etching is particularly useful for developing the structure of stainless steels, as it effects a uniform attack and tends to prevent surface passivity during etching. Fig. 5 shows a diagram of apparatus suitable for electrolytic etching of the stainless steels.

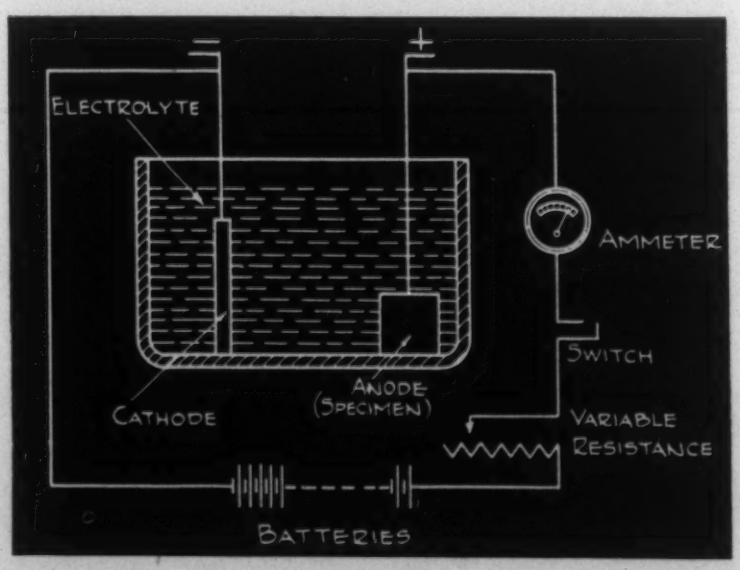
The solutions employed as electrolytes depend upon the nature of the alloy and the constituent to be revealed. Table II lists the solutions generally used in the electrolytic etching of the stainless steels.

It is not considered proper to comment on the merits of the various reagents given in Table I and II, because it is believed that the final result depends largely upon the individual's experience with a particular reagent. Each of the reagents possesses distinctive merits and disadvantages; thus some produce a one-color structure in which the grain boundaries are emphasized, others color the individual grains in relation to their orientation, and some preferentially etch certain constituents. However, the "Aqua Regia-Glycerol" reagent proposed by Vilella and the alcoholic-hydrochloric electrolyte proposed by Merritt are generally recognized as the best reagents for all round use in etching stainless steels for microscopic examination. For revealing free carbides, Murakami's reagent and Groesbeck's sodium cyanide reagent are generally considered the most reliable.

Heat tinting can be used to effect in differentiating between the various constituents in the stainless steels as illustrated by Figs. 6, 7 and 8.

The constitution of the stainless steels has been thoroughly investigated during the past few years and numerous articles and books have appeared on the subject. The fundamental changes occurring

Fig. 5. Diagram of apparatus for electrolytic etching the stainless steels.



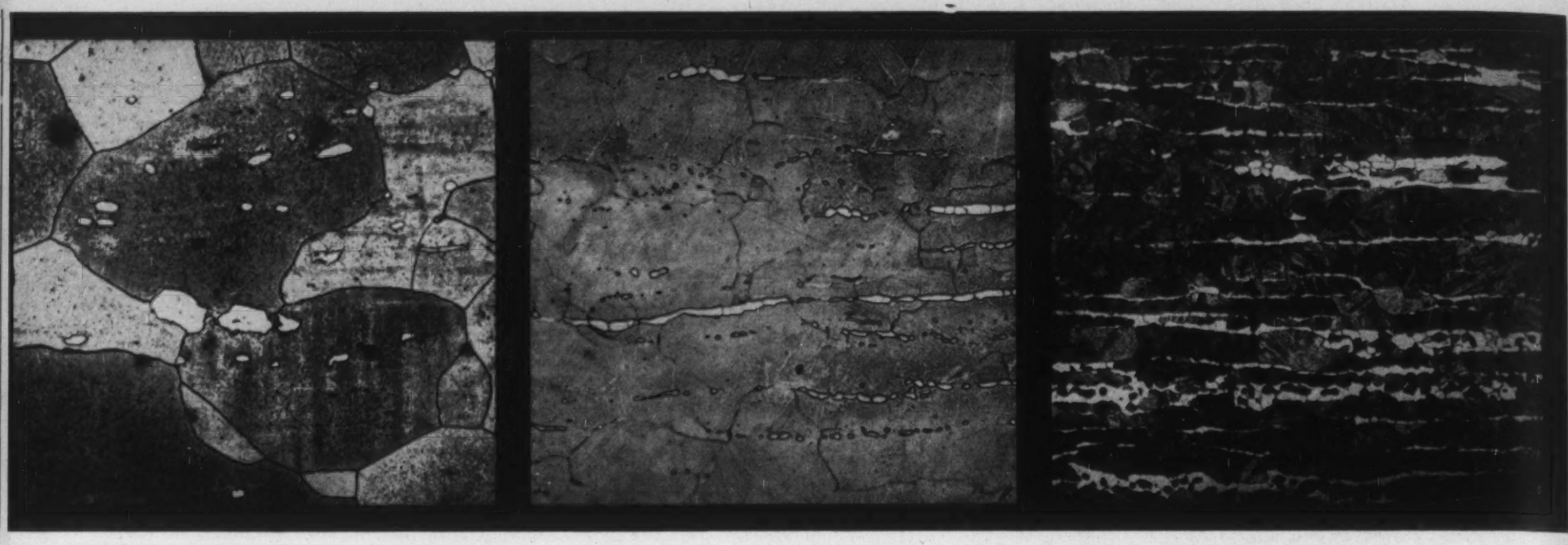


Fig. 6. (Left) Etched and heat-tinted structure of 27 per cent Cr stainless steel. White areas, carbides in ferrite matrix. Heat-tinted at 1100 deg. F. for 5 min. Mag. 200X. Fig. 7. (Center) Etched out and heat-tinted structure of 18 and 8 stainless steel. White areas, delta ferrite in austenitic matrix. Heat-tinted at 1100 deg. F. for 5 min. Mag. 200X. Fig. 8. (Right) Etched and heat-tinted structure of 12 per cent Cr stainless steel. White areas, alpha ferrite in martensitic matrix. Heat-tinted at 1100 deg. F. for 5 min. Mag. 200X.

when these alloys are heat treated is fairly well known among users, but it is deemed worth while to briefly discuss some of the more important of these changes which will be helpful in understanding and interpreting the structural transformations occurring in processing the stainless steels.

Importance of Chromium

The element imparting the valuable properties of high resistance to heat and corrosion to the stainless steels is chromium. It possesses the unique property of protecting itself against corrosion in spite of a great tendency, at the same time, to unite with oxygen. In fact, it is generally believed that a fresh surface of chromium metal, when exposed to the air, becomes oxidized almost instantly, but that this thin and invisible film of oxide is itself of such a nature as to be continuous, impervious, and highly stable. Thus, the corrosive action which begins with great rapidity is abruptly terminated the very instant it begins. The existence of such a film on the surface of the stainless steels is no idle speculation as it has actually been isolated. Further, the film can be made more resistant, and possibly thicker, by exposure to highly oxidizing media such as nitric acid and potassium dichromate.

This valuable property of pure chromium is also conferred upon the base metal iron when it is present in amounts above about 10 per cent. Pure chromium is expensive and in addition is not sufficiently ductile for hot or cold forming. Consequently, it is a fortunate circumstance that as little as 10 per cent chromium, when in solid solution in iron, will impart true stainless characteristics to the resulting alloy. Also, these iron-chromium alloys, up to 30 per cent chromium, are workable and can be fabricated by any of the ordinary methods. Thus far, out of the many possible elements which could be alloyed with iron or steel, chromium is the only one yet found which will impart to these base metals, at a reasonable cost, high resistance to corrosion and oxidation. Gradual increase in chromium content above 10 per cent results in a progressive, though not proportional increase in resistance to heat and corrosion.

Nickel and Other Elements

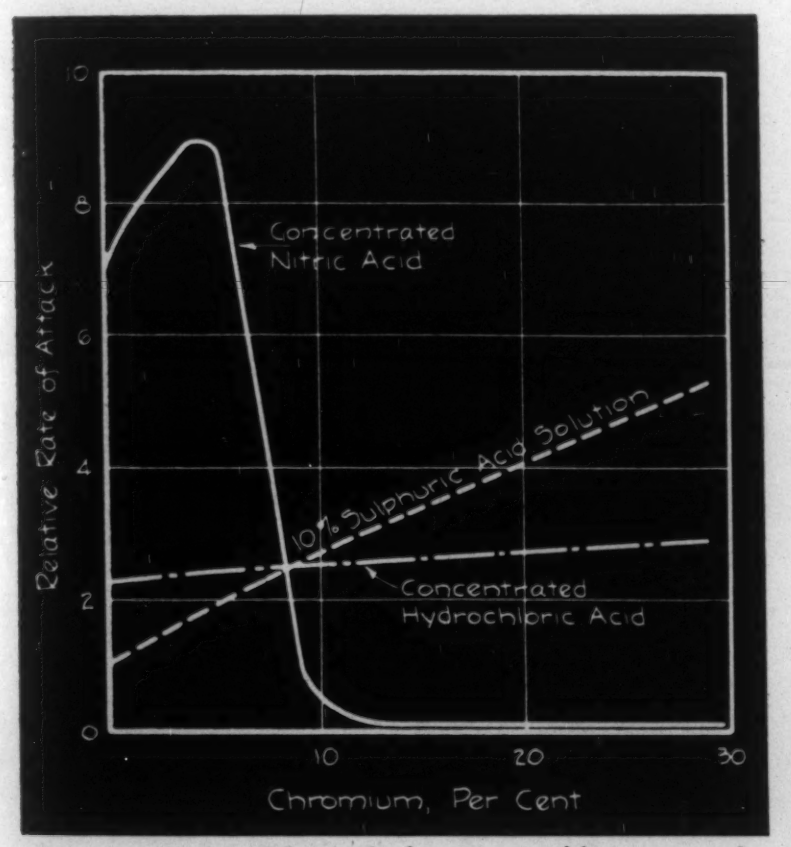
Although chromium is the chief alloying element in iron and steel for inhibiting corrosion and oxidation, other elements may be alloyed, in combination with it, to obtain special characteristics. The most important of these is nickel and when it and chromium are added in correct proportions, the resulting alloy, of which the well known "18 and 8" stainless steel is a type, is non-magnetic, extremely ductile and highly resistant to most corrosive conditions encountered in industry. In addition, other elements are added, such as molybdenum to increase resistance to certain acids, and silicon to reduce scaling and oxidation at high temperatures. Sulphur and selenium in amounts above about 0.15 per cent impart free-cutting and non-seizing properties. Tungsten increases strength at elevated temperatures and titanium and columbium are helpful in minimizing carbide precipitation in the austenitic stainless steels, thus reducing their susceptibility to intergranular corrosion. However, from a practical standpoint, intergranular

corrosion of the 18 and 8 stainless steels can be minimized by maintaining the carbon content below about 0.07 per cent.

As chromium is the chief alloying element in the stainless steels, the metallurgy of these alloys is essentially a study of the effect of chromium on the iron-carbon constitutional diagram. It is general assumed that chromium exists in solid solution with iron in all concentrations provided the carbon content is extremely low. Full corrosion resistance is only developed when all the chromium is retained in solid solution. In the presence of a small percentage of carbon (over about 0.02%), chromium combines with it to form carbides, generally considered to have the chemical formula of Cr_4C, containing about 94 per cent Cr with possibly some iron and manganese also present. Regardless of their exact formula, it is sufficient to know that these chromium-rich carbides occur as dispersed particles in the annealed straight-chromium stainless steels and in the "sensitized" 18 and 8 stainless steels, thus impoverishing the surrounding alloy of chromium with consequent reduced resistance to corrosion.

It follows then that the corrosion properties of the stainless steels are in proportion to the amount of chromium retained in solid solution, and any undissolved carbides present in the structure represents a wastage of effectual chromium. At high temperatures these carbides are dissolved and may be retained, partly in supersaturated solution by rapid cooling. In the annealed straight-chromium stainless steels, the maximum amount of chromium is retained in solid solution by maintaining a low carbon content. In the case of the hardenable types of stainless steels, with carbon content below about 0.30 per cent, the carbides are dissolved by heating to 1850 deg. F. and retained in supersaturated solid solution by cooling rapidly. Thus, the entire amount of chromium present becomes effective as it is in solid solution.

(*To be Continued*)



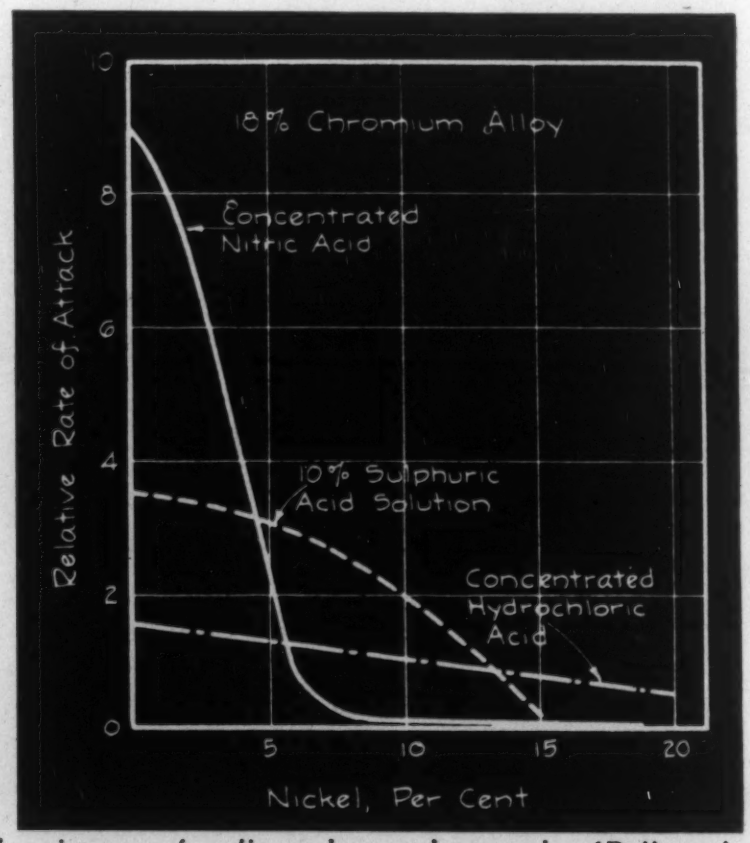


Fig. 9. (Left) Effect of chromium additions on the acid resistance of ordinary low carbon steel. (Rollason)
Fig. 10. (Right) Effect of nickel additions on the acid resistance of 18 per cent chromium stainless steel. (Rollason)

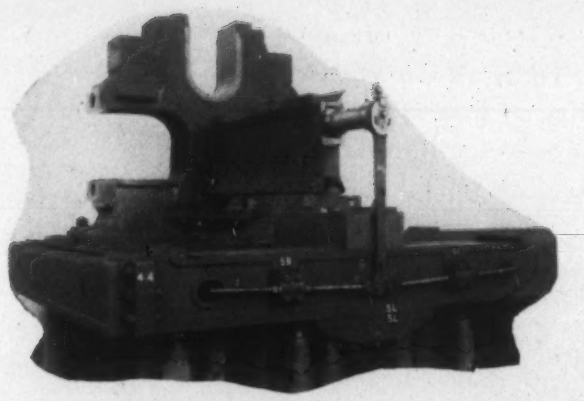
Special-Iron Castings for He

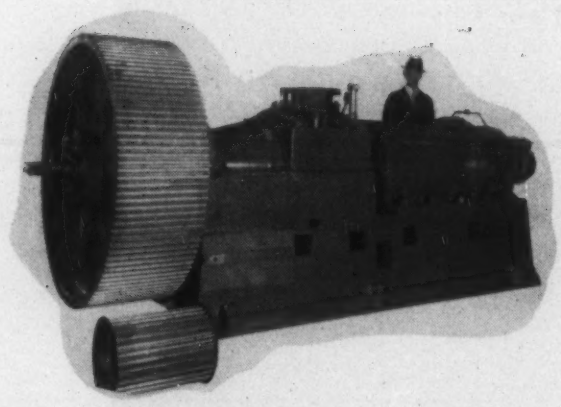
BY S. S. BOARD, JR.
Engineer, Farrel Birmingham Co., Inc., Ansonia, Conn.

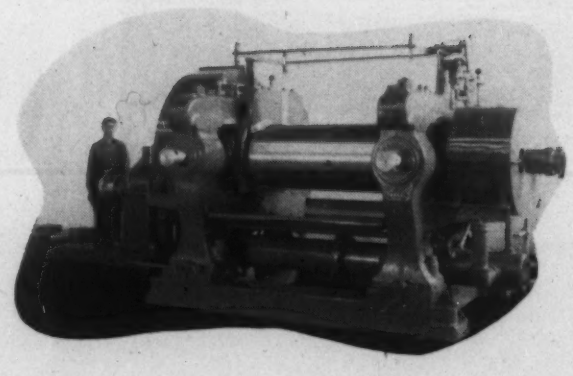
Modern machine tools and other heavy machinery must operate under loads and speeds unheard of a decade ago, yet the tolerances and clearances involved in the design of such products have not permitted compensating increase in sections. The engineer's answer to this "squeeze play" has been the wider use of metal-forms of greater strength and toughness than ordinary cast iron—welded steel, steel castings, alloy cast iron, special-process iron castings, etc.

At Farrel-Birmingham the desired balance between product performance, processing flexibility and production costs has been found in the use of Meehanite for all castings formerly made of gray iron and for some formerly made of steel. Meehanite is a special cast iron made by a proprietary process involving the use of calcium silicide additions together with systematized control of charge, iron composition, melting and pouring temperatures, mold practice, etc. Guaranteed minimum tensile strengths up to 50,000 lbs. per sq. in. are available in the most-used grades of this material, with higher strengths possible through heat treatment or alloying. In changing over from ordinary cast iron or alloy iron to Meehanite, sections were generally not redesigned or reduced, but were stressed much higher, greater horse-power being put into each machine and greater output extracted.

Glimpses of some of the products and components that we are now making of Meehanite are presented on this page. In their manufacture and operation other advantages have been noted—highly accurate surface-machining qualities because of the close-grain structure and uniformity of the material, ease of casting of Meehanite, lower mass-sensitivity than ordinary cast iron, better corrosion resistance, amenability of certain grades to heat treatment and flame-hardening, etc. Close-up views of several operations in the manufacture from Meehanite of a heavy-duty roll grinder and other products appear on the following pages.

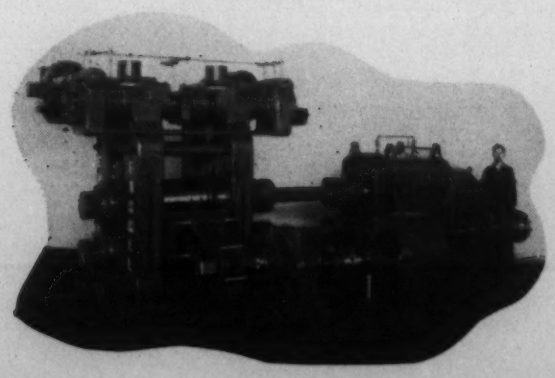


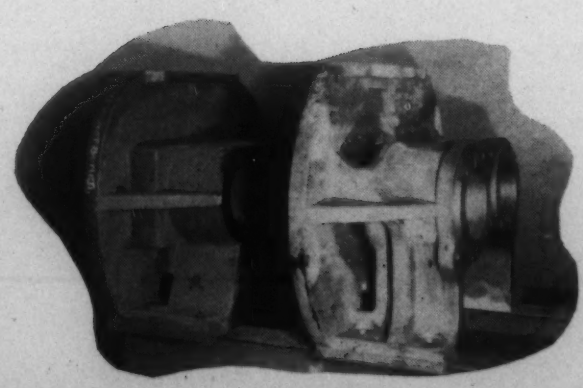




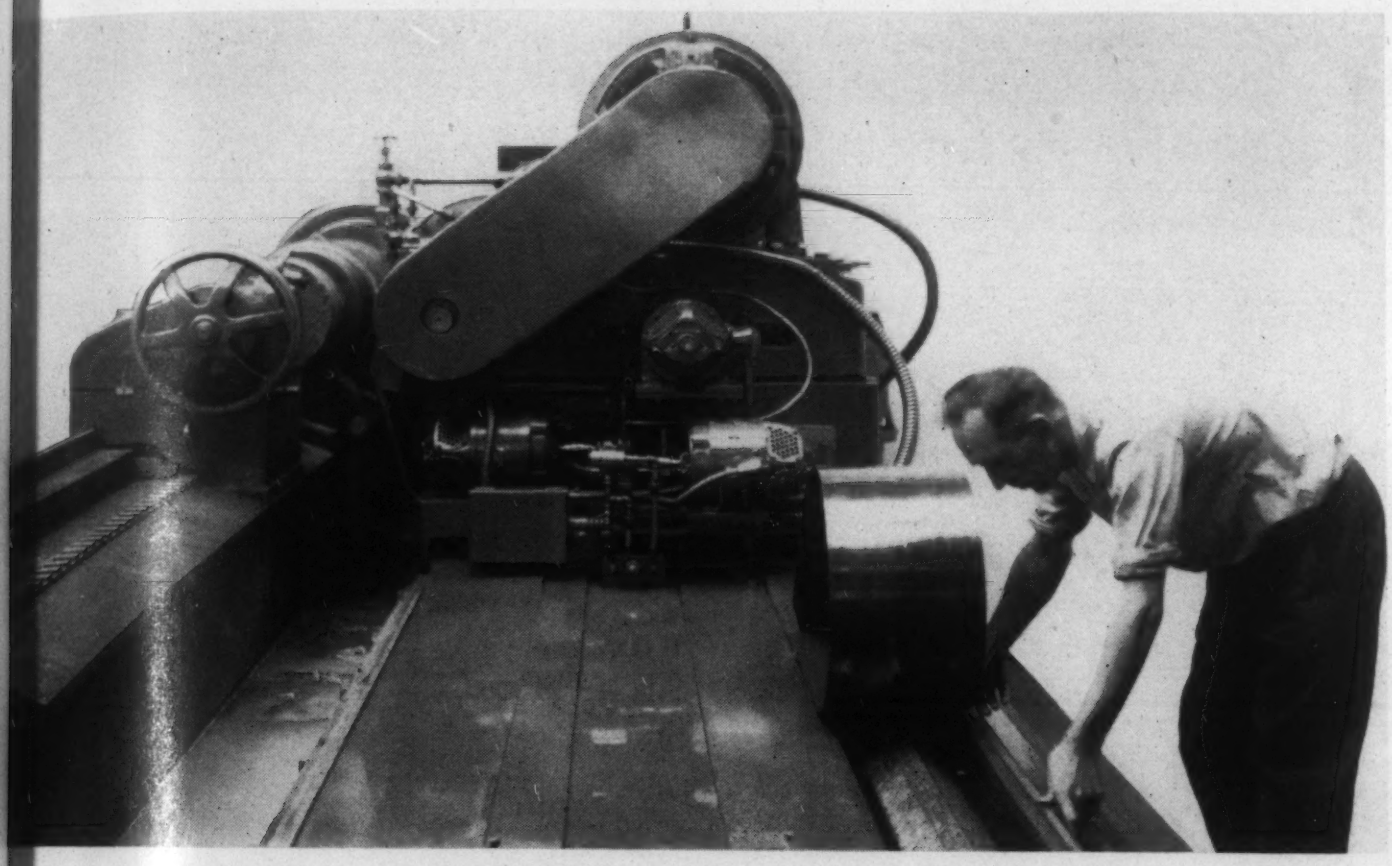
At left: Top—A sugar-mill housing, bedplate and scraper, all of Meehanite, for strength and wear resistance. Middle—Drive gears on Gordon plasticators are made of Meehanite to withstand stresses, shocks and wear. Bottom—Many of the castings in this 22 in. x 48 in. plastics mill and drive unit are made of Meehanite.

Below: Left—An 18 in. x 24 in. rolling mill, reduction drive and pinion stand, the principal castings of which are made of Meehanite. Middle—End frames for Banbury mixer, which are required to have high strength. Right—The high damping capacity of these Meehanite drive cases for the Maritime Commission C-1 ships contributes to the smooth, quiet operation of the propulsion units.





Heavy Machinery—A PICTORIAL ACCOUNT



In the heavy duty roll grinder shown here, the inverted V ways are cast separately from the bed and a different type of Meehanite is used for each. The so-called GE grade is employed for the beds, which must support the work and wheel units and dampen vibrations that might be transmitted to the work. The GC grade is used for the ways, for which a close-grained wear-resisting metal easily scraped to a smooth finish is required.

In casting the 18-ton roll grinder bed, Farrel-Birmingham employs the Randupson process, in which the material of the mold is a silica sand bonded with cement. The mold material is formed into blocks, and the illustration shows the core-setting operation. Metal enters the mold simultaneously from gates at both ends.

After the Meehanite casting is cleaned of sand it is placed in the stress-relieving furnace, illustrated, to remove casting stresses. This assures that the bed will not change its shape after machining. The complete cycle requires 48 hrs.; the temperature ranges from room temperature at the beginning to a maximum of 1200 deg. F. and back to room temperature when the bed is removed.

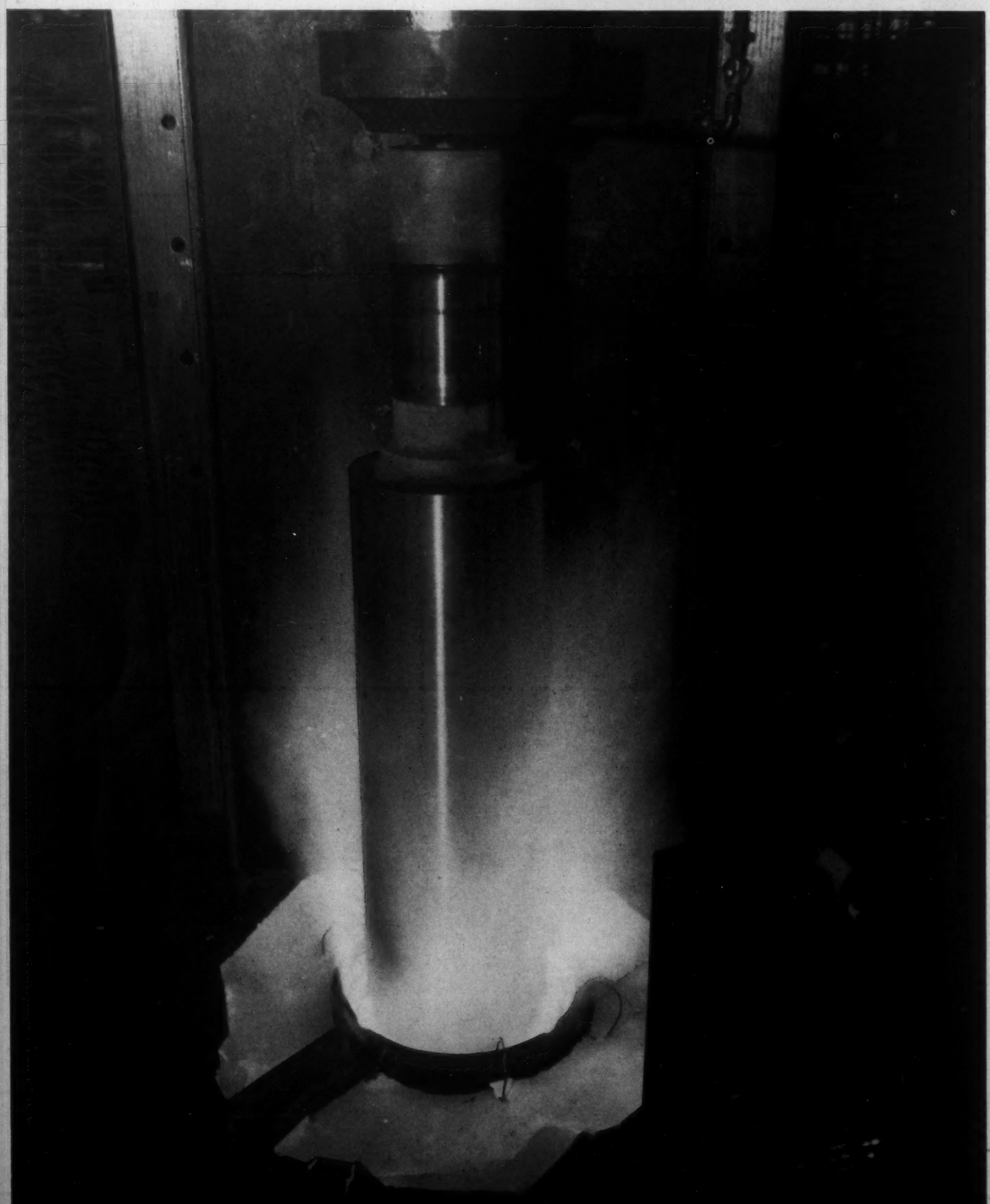
Here is the bed casting, ready for machining. Note that the bed was molded and cast in the opposite position to that in which it will ultimately be used.

The important operation of planing the front sidewall of the 28 ft., 8 in. long grinder bed is shown at the left. High speed steel tools are used and the easy machinability of Meehanite is a real asset in finishing these castings.

The outstanding machining properties of Meehanite are especially evident in finishing the ways of the roll grinder. A highly-accurate hand-tooled finish is possible, and resistance to wear and abrasion of the ways is so great that surface hardening is unnecessary. In this picture the transverse way of the wheelhead sub-base is being hand-scraped, while the roll crowning device is being assembled on the sub-base.

Here another roll grinder component—the headstock—is being bored on a horizontal boring mill to produce the sleeve into which the center is later driven. The Meehanite headstock casting is 4 ft., 6 in. long, with a wall thickness of 1¼ in. in most places. Since dead-center precision is required, the importance of having an accurately machinable material is evident. Here again, and also in the next-shown operation, high speed steel tools are used.

The Banbury mixers so widely used in the rubber and plastics industries draw heavily on strong, tough, accurate-finishing materials. This is a view of a 64-in. cut spur drive gear blank for such a mixer being finish-turned on a 72-in. vertical boring mill before tooth-cutting. The Meehanite casting has a 15-in. face and weighs 5150 lbs.



Flame-hardened Meehanite rolls are used for rubber and plastics working, and many other purposes. For large rolls a special vertical roll-hardening machine like that illustrated is used, the roll being rotated while its surface is treated by the torch-and-quench unit; surface hardnesses over 500 Brinell are produced this way. The absolute structural uniformity essential to the successful flame-hardening of iron castings is characteristic of Meehanite.

Diffusion in Alpha Solid Solutions of Aluminum

by R. F. Mehl, F. N. Rhines and K. A. von den Steinen

Head, Dep't. of Metallurgy, Ass't. Prof. of Metallurgy, Formerly Fellow in Metallurgy, Carnegie Institute of Technology, Pittsburgh, respectively. The last is now with the American Smelting & Refining Co., Perth Amboy, N. J.

THE DIFFUSION OF VARIOUS METALS into solid aluminum is of importance in a number of ways: A knowledge of the factors determining rates of diffusion in solid alloys will increase as more data are obtained; the process of homogenization and the process of precipitation-aging are both processes the rates of which are at least in part dependent upon the rates of diffusion; in the annealing of alloy sheets coated with pure aluminum, it is important that the pure aluminum coating shall not be contaminated by too extensive diffusion outward of the alloying elements in the core alloy—by a knowledge of diffusion coefficients, heat-treating cycles may be devised to avoid this.

Measurements of the rates of diffusion of a number of elements in aluminum have been made by G. Grube and R. Haefner,[1] A. Burkhardt and G. Sachs,[2] H. R. Freche,[3] R. M. Brick and A. Phillips,[4] W. Bungardt and F. Bollenrath;[5] and A. Beerwald,[6] whose results are assembled in Fig. 1. These values show the variation of the diffusion rate with temperature, but not with alloy concentration. Since in some cases the diffusion coefficient is changed as much by a variation of one per cent in concentration as by a variation of 50 deg. in temperature, it is evident that the effect of concentration is an important one.

Object of the Research

The present research has been designed to determine the variation of the diffusion coefficient with alloy concentration as well as with temperature in the aluminum-rich solid solutions in the systems Al-Cu, Al-Mg, Al-Si, Al-Ag, and Al-Zn. A summary of the results is shown in Fig. 1, where the shaded areas denote the range of values of the diffusion coefficient between the concentration limits specified.

Many of the previously published values fall within the shaded areas of Fig. 1, suggesting that the differences among the various investigators have not always been the result of errors in measurement, but may sometimes have been caused by a difference

Fig. 1. Previously reported values of the diffusion coefficient of Cu, Mg, Si, Ag and Zn in Al indicated by points and identifying symbols. Shaded areas indicate the range of the diffusion coefficient between the alloy concentration limits indicated as determined in the present research.

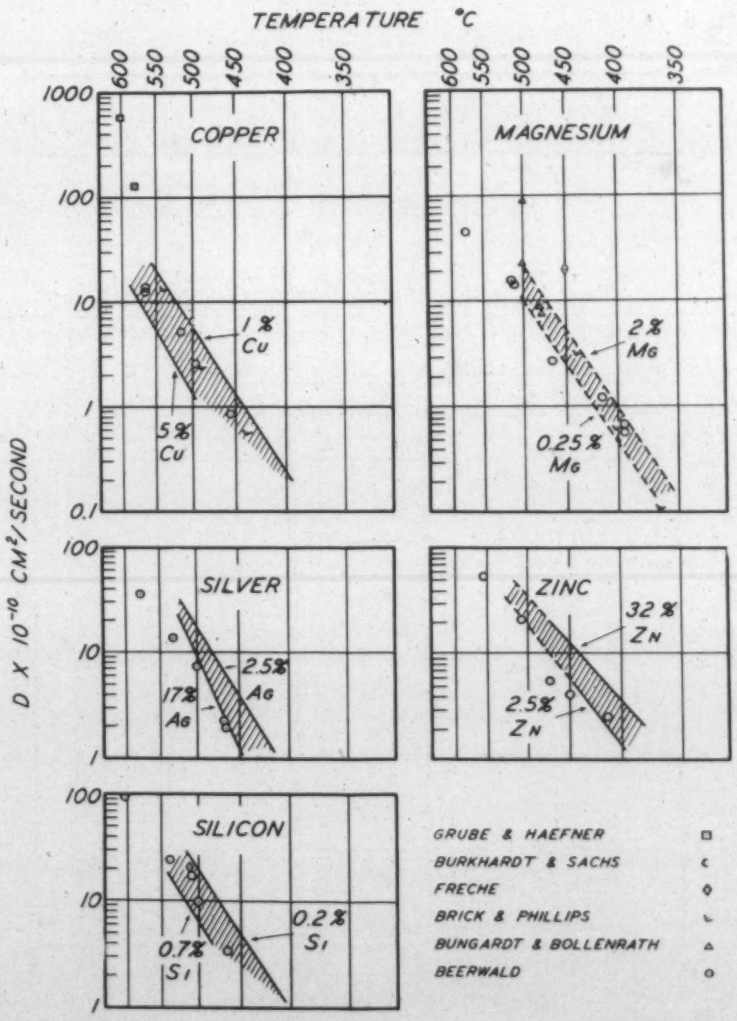


Table I.—Core Analysis—Balance Al

Alloy No.	Si	Fe	Cu	Mg	Ag	Zn
100, 200, 300	0.01	0.01	6.96	—	—	—
1,600	0.01	0.01	0.01	2.49	—	—
1,800	2.54	0.01	0.01	—	—	—
1,900	0.01	0.01	0.02	—	10.28	—
2,000	0.01	0.01	0.03	—	19.82	—
2,100	0.01	0.01	0.01	—	—	20.18
2,200	0.01	0.01	0.01	—	—	40.02
Surface Layers	0.01	0.03	0.01	—	—	—

Table II

Diffusing Metal	Intermediate value of Q cal. per gm. mol.
Cu	33900
Mg	32200
Si	31500
Ag	38500
Zn	25800

Fig. 2. Variation of the diffusion coefficient with concentration at 504 deg. C., 448 deg. C. and 400 deg. C. in aluminum-copper alloys.

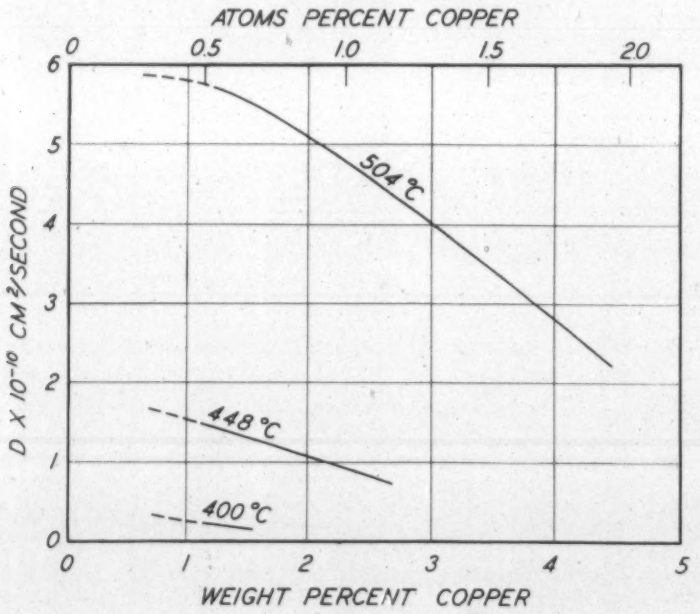
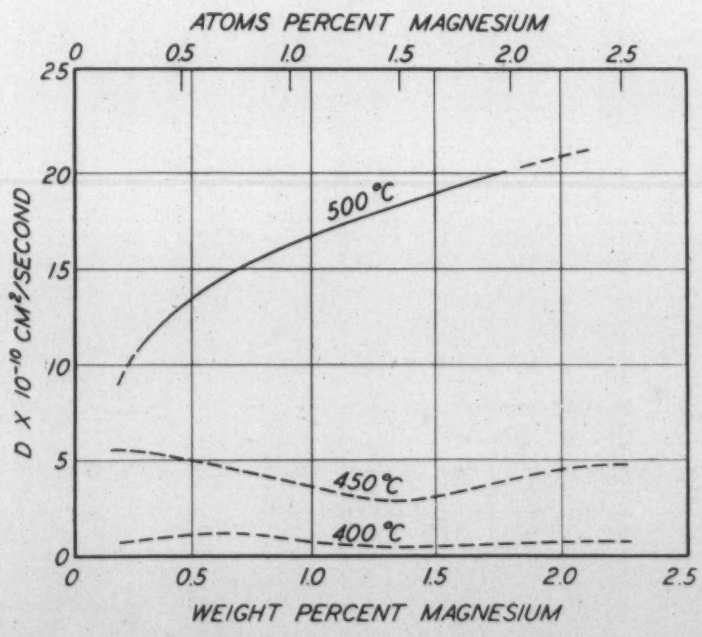


Fig. 3. Variation of the diffusion coefficient with concentration at 500 deg. C., 448 deg. C. and 400 deg. C. in aluminum-magnesium alloys.



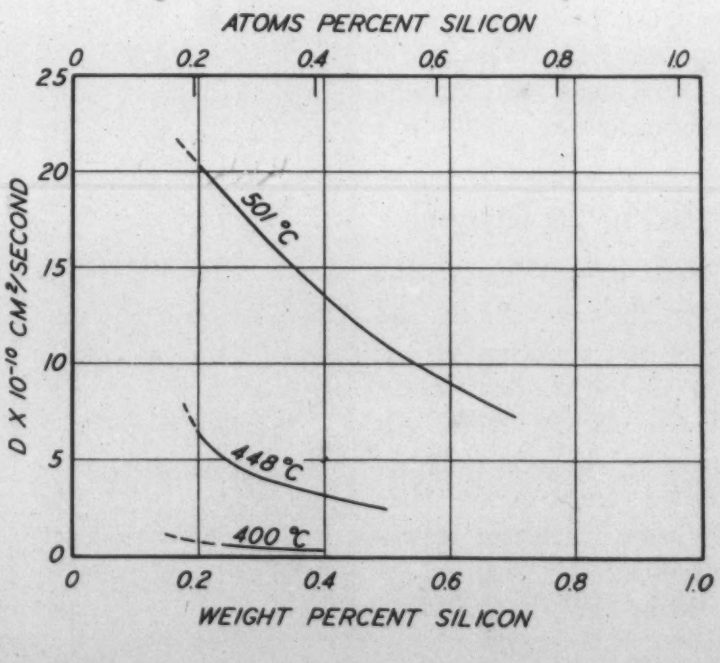
in the alloy concentration with which each value is to be associated. Where experimental errors have occurred their source lies most commonly in the presence of a film of aluminum oxide between the two parts of the diffusion couple, for aluminum oxide is capable of interfering with diffusion and its presence may lead to low values for the diffusion coefficient. Thus the values given by Beerwald, who simply brought pieces of pure aluminum and an alloy into contact without extensive precautions to eliminate the oxide film, are lower than those of other investigators who took more elaborate precautions to insure intimate contact at the diffusion interface.

Among the techniques that have been used the one that appears to give the most positive assurance of the destruction of the oxide film is that employed by Freche, who rolled composite slabs of pure aluminum and the aluminum alloy containing the diffusing element. In this way the total area of oxide remaining at the interface in the finished sample is limited to the original contact area before rolling and the oxide must furthermore be disintegrated and widely dispersed so that its influence upon diffusion is minimized.

Experimental Procedure

Sheets of pure aluminum, 0.375 in. thick, rolled from a commercial 7 in. x 14 in. x 28 in. ingot were annealed for two hours at 413 deg. C. Alloys, Table I, made from pure aluminum were melted in plumbago crucibles and cast as ingots 1.5 in. x 8 in. x 7 in., weighing 8 lbs. each. These were taken from the mold hot, placed between pure aluminum slabs, cooled to 455 deg. C., and reduced 0.125 in. in

Fig. 4. Variation of the diffusion coefficient with concentration at 501 deg. C., 448 deg. C. and 400 deg. C. in aluminum-silicon alloys.



thickness by rolling to produce a bond. The silver alloys were made in 4-lb. ingots. To promote homogenization, the copper, magnesium, and silicon slabs were then heated for 12 hrs. at 477 deg. C., of which time about 5 hrs. was required to reach the specified temperature. The silver and zinc alloys were heated for a similar time at 385 deg. C. Upon removal from the furnace, the slabs were cooled to a suitable working temperature and rolled to a thickness of 0.375 in., the copper, magnesium, and silicon alloys being rolled at 455 deg. C. and the silver and zinc alloys at 315 deg. C.

From the most perfect section of each finished sheet, strips ½ in. x 6 in. were cut for the diffusion studies. Samples of each alloy were heated in duplicate for 100 hrs. at 400 deg. C., 450 deg. C., and 500 deg. C. (except the zinc alloys which were treated at 400 deg. C. and 450 deg. C. only). The distribution of the alloying element in the coat and core of the sample was then determined by machining off layers and analyzing the steps either chemically or spectrographically.

For chemical analysis layers 0.005 in. thick were cut with a shaper parallel to the interface between the coat and core of the sample, the location of which was determined by etching the edges of the sample to reveal the junction. Each layer was analyzed separately and all of the metal taken in each cut was included in the analytical sample so that a true average composition at each level was obtained. In all, 10 layers and the core material were analyzed for each sample.

For the spectrographic analyses the samples were cut in a series of steps, each 0.005 in. deeper than the next, and the test spark was located in the center of each step. Small variations in the local composition of the underlying alloy as well as in the regularity of the interface between the coat and core have a marked effect upon the results of the spectrographic analyses and for this reason it was found necessary to average a number of readings in order to obtain values for the computation of the diffusion coefficient.

Since the samples used in this investigation were all heated for various periods at different temperatures during their fabrication, it was necessary in calculating the diffusion coefficient to take into account a definite amount of preliminary diffusion; the amount of this preliminary diffusion was determined by analyzing "blank" samples that had no heat treatment subsequent to fabrication.

The computation of the diffusion coefficient by the methods of Grube and Matano has been discussed in previous papers.[7,8] In order to compensate for diffusion during fabrication a simple modification in the computation is required. The diffusion coefficient is computed in the usual way except that the time of diffusion is taken as the sum of the experimental time noted and an unknown value t corresponding to the time equivalent of the diffusion during fabrication. The diffusion coefficient is simultaneously computed from the "blank" sample in terms of the unknown time, t. This gives two simultaneous equations with two unknowns, t, and the diffusion coefficient, D, and from which the value of the latter is obtained by substitution.

Discussion of Results

The results are presented in Figs. 2 to 6. In all cases where the Matano method of analysis is applicable (in single phase systems) it has been used.

Fig. 5. Variation of the diffusion coefficient with concentration at 508 deg. C., 448 deg. C. and 400 deg. C. in aluminum-silver alloys.

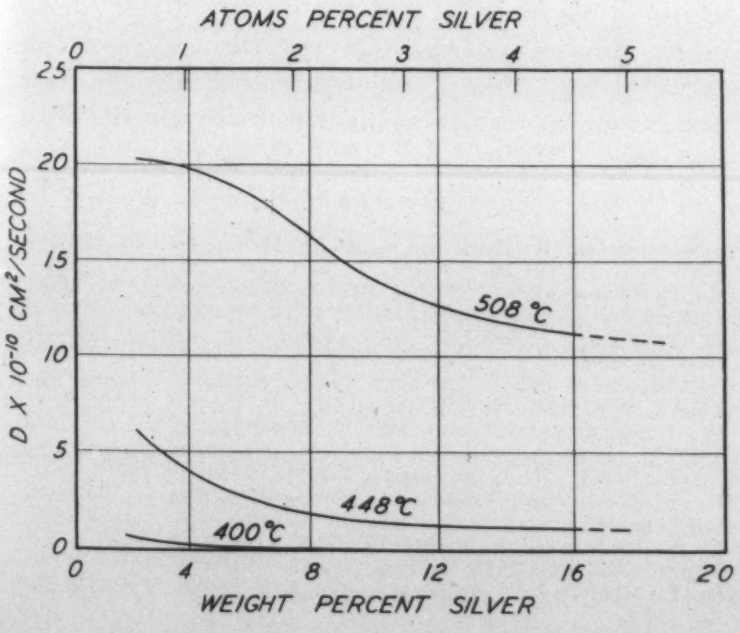
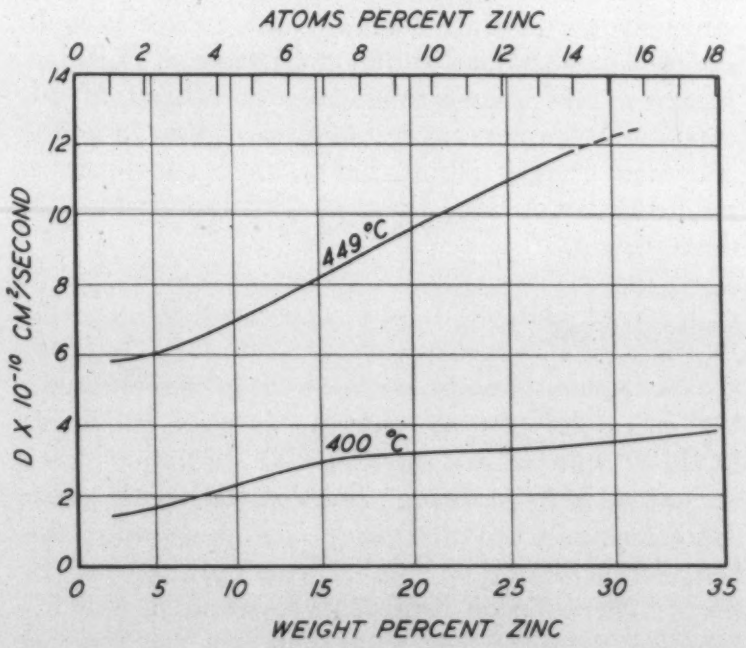


Fig. 6. Variation of the diffusion coefficient with concentration at 450 deg. C. and 400 deg. C. in aluminum-zinc alloys.



Elsewhere the Grube method has been employed. Although the Grube solution is derived upon the assumption that the diffusion coefficient is independent of concentration, it has been found that the values obtained by its use when it is applied over a series of concentration ranges agree very closely with those obtained by the Matano method. Its use for the determination of the diffusion coefficient as a function of concentration in cases where the Matano solution cannot be applied appears not to have resulted in an error larger than those inherent in the experimental data.

The accuracy of the determination of diffusion coefficients has been discussed in connection with similar studies upon the alloys of copper[8] where it was pointed out that the largest errors are introduced by (1) inaccuracy in chemical analysis, (2) uncertainty in the temperature of diffusion, and (3) uncertainty in the measurement of the slopes of the penetration curves. The chemical analyses may be regarded as accurate to within ± 0.08 per cent at low concentrations and 0.3 per cent at high concentrations for the alloys containing Cu, Ag, and Zn. The spark spectrographic method was used for the Mg and Si analyses; because of the marked influence of small irregularities in the interface when analyses are taken at single points, the effective accuracy is somewhat less than that normally ascribed to spectrographic determinations, perhaps ± 0.2 per cent. As a result, the diffusion coefficients reported for Mg and Si are not so accurate as those for Cu, Ag, and Zn; the values for Mg at 400 deg. C. and 450 deg. C., owing to an imperfect weld between the pure aluminum and the alloy, must be considered as only approximations; they have not been used in drawing Fig. 1 and appear only as dashed lines in Fig. 3.

All heat treatments were carried out in a temperature-controlled muffle furnace equipped with a heavy aluminum block that limited the temperature range to ± 1 deg. C. No appreciable error is to be assigned to variations in the temperature of diffusion. Errors in the measurement of the slopes of the penetration curves are greatest near the zero and maximum concentration limits and, consequently, results have not been reported for concentrations in these ranges.

General Trends

Few general trends are evident in these results. We may note, however, that the diffusion coefficient increases with increasing solute concentration when the solute is low-melting, and decreases with solute concentration when the solute is high-melting; this behavior is orthodox. Other relationships may be noted: The diffusion coefficients appear to approach a common value of $20\text{-}25 \cdot 10^{-10}$ sq. cm. per sec. at 500 deg. C. in the systems with Si, Ag, and Zn, and a value $6 \cdot 10^{-10}$ sq. cm. per sec. in the systems with Cu and Mg. This behavior may be fortuitous; it will be remembered that in Cu-rich solid solid solutions the diffusion coefficients approached a common value at zero concentration,[8] but it will be observed in the present case that a single common value does not obtain; evidently the explanation advanced in the former case[8] cannot be advanced here.

The precision of the measurements does not warrant a calculation of the activation heat of diffusion Q as a function of concentration; an average or intermediate value may be obtained by drawing straight lines with slopes intermediate between the two extremes of the shaded areas in Fig. 1; these values are listed in Table II. The magnitude of these values is the expected one. It will be noted that the value for silver, 38,500 cal., is much in excess of the activation heat approximated from the rates of precipitation in Al-Ag alloys; this demonstrates the importance of factors other than diffusion in determining the rates of precipitation,[9] and, of course, shows also that the activation heat calculated in this way is too low, which is to be expected.

Summary and Acknowledgment

The diffusion coefficient D has been measured as a function of temperature and alloy concentration in 5 Al-base solid solution systems. At 500 deg. C., for example, the following ranges of values of D are found: 5.8 to 1.5 x 10^{-10} sq. cm. per sec. between 1 and 5 per cent copper; 11 to 21 x 10^{-10} sq. cm. per sec. between 0.25 and 2 per cent magnesium; 20 to 7.5 x 10^{-10} sq. cm. per sec. between 0.2 and 0.7 per cent silicon; 20 to 11 x 15^{-10} sq. cm. per sec. between 2.5 and 17 per cent silver; and (by extrapolation) 20 to 38 x 10^{-10} sq. cm. per sec. between 2.5 and 32 per cent zinc. Values of the activation heat of diffusion are tabulated.

We wish to express our appreciation to the Aluminum Co. of America, and particularly to Dr. F. C. Frary, director of research, for their kindness in awarding one of us a fellowship and also for their cooperation in furnishing us with materials and with analyses.

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Electrical Resistance Furnaces For High Temperatures

by PAUL SCHWARZKOPF

President, American Electro Metal Corp., Yonkers, N. Y.

A RETROSPECT ON THE PROGRESS made recently in the heating of electric furnaces by resistance heating-elements shows clearly certain trends of development, which are to be dealt with in the following article.

The transformation of the electric energy, supplied to a resistance furnace, into heat energy, takes place either in the resistance of solid conductors or of molten salts (electrolytes). While in practice the upper temperature limit in heating by electrolytic conductors has probably been reached today, this does not seem to be the case when applying materials of the group of solid conductors.

Four Heating Elements

There are four different kinds of such heating elements:

1. *Resistance elements (wires, strips, etc.) of metals or alloys* which are freely exposed to the furnace atmosphere, and which mostly are supported at various points by ceramic supports.
2. *Resistance heating rods on a silicon-carbide basis* (made from a mixture of carbides and ceramic filling material) which frequently are only supported at the two ends and are also freely exposed to the furnace atmosphere.
3. *Heating elements of metals with a high melting point*, working in an atmosphere of protective gases with high surface temperature.
4. *Heating elements containing metals with a high melting point* which are separated from the furnace atmosphere by a gas-proof protective casing.

The use of heating elements of the first kind is limited to furnaces with temperatures up to about 1200 to 1300 deg. C. (2200 to 2400° F.) The highest possible temperature depends, of course, on the use. Besides, at higher temperatures, the lifetime of the rods is strongly influenced by chemical reactions, evaporation of single alloy components, etc. Furthermore, the lifetime is determined by the method of working the furnace, (intermittent or continuous working), by the gases and vapors given off by the heated body, by the arrangement of the heating elements (danger of sputtering in the melting furnaces), and by many other details of construction and operation. There are only slight possibilities of further raising the working temperature by development of new resistance alloys.

Silicon-carbide heating elements are suitable for temperatures up to about 1400 deg. C. (2550° F.), sometimes slightly more. The use of these heating elements is limited by the fact that at this high temperature a furnace atmosphere containing, for example, water vapor, deteriorates the rods more rapidly. It is hardly possible further to increase the temperature of the rod, i. e., to increase considerably the heat output per surface unit. Owing to the relatively small heat conductivity of this resistance material, as compared with metallic conductors, the temperature in the center of the rod is very much higher than that on the surface. Therefore, the rod starts to deteriorate chemically from the inside. On the other hand, this relatively small thermal and electrical conductivity has the advantage that the voltage drop on the rod at low currents is relatively high, even in the case of large rod cross sections, and that the losses of heat flowing to the ends of the rod are relatively small. In order to decrease further the "Joule" heat at the ends, metal is introduced into this part, and sometimes the cross section of the ends is increased. The "aging" of the rods (change of resistance) is a disadvantage regarding the operation of the transformer and the possibility of changing single rods.

Use of a Protective Atmosphere

For some time metals with a high melting point, like molybdenum and tungsten (melting points about 2630° C. and 3380° C. respectively) have been used for special purposes in furnaces filled with protective gas. Such a construction is shown in Fig. 1. It is a pusher-type furnace with a hydrogen atmosphere, used for the reduction of refractory oxides and other general heat treatment purposes. The heating elements are mounted inside the furnace, above and below the charge, and consist of molybdenum ribbons arranged in a zigzag winding. In an atmosphere

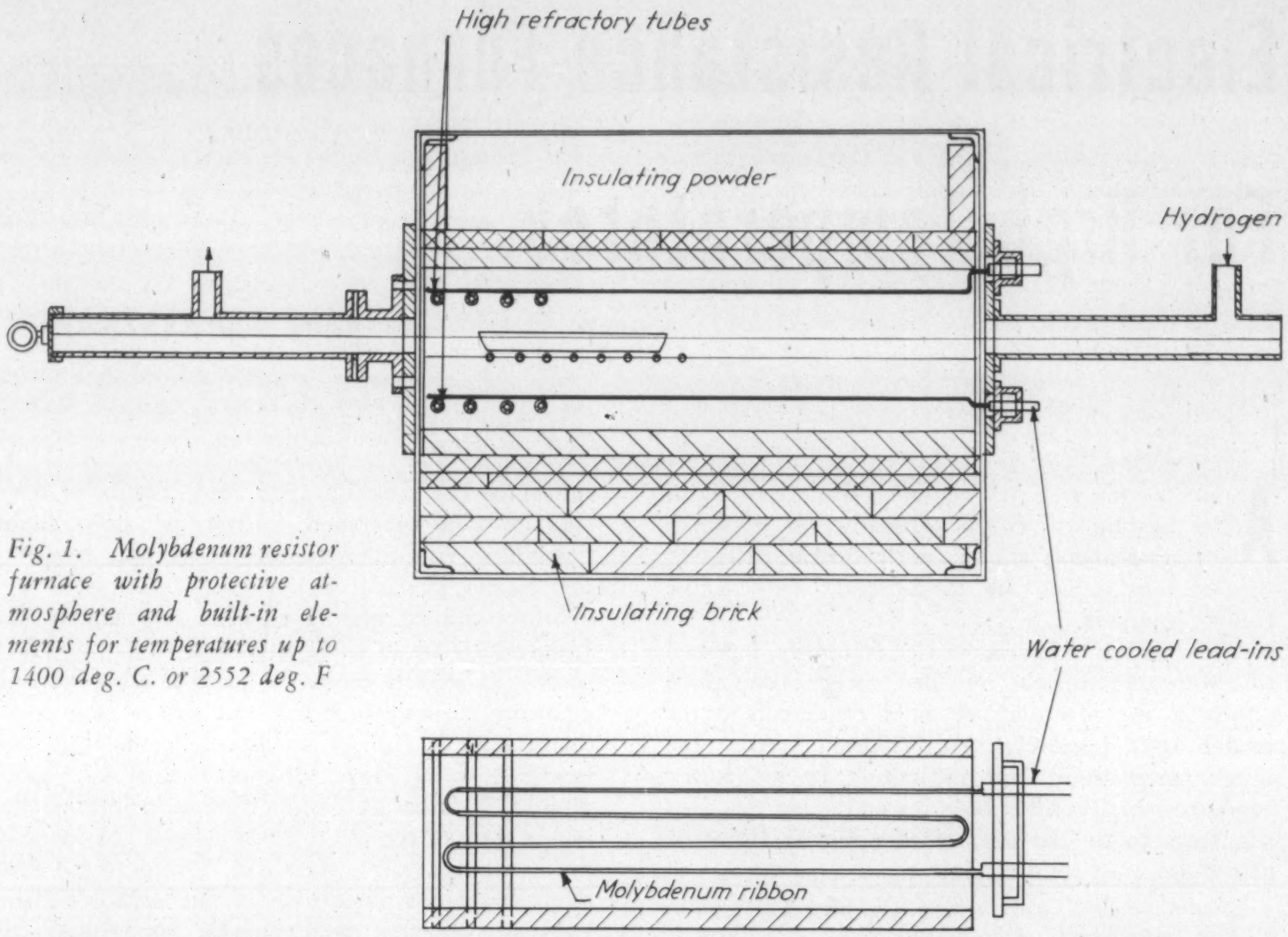


Fig. 1. Molybdenum resistor furnace with protective atmosphere and built-in elements for temperatures up to 1400 deg. C. or 2552 deg. F

containing oxygen and water vapor, etc., these metals would form oxides, which, owing to their high vapor pressure, would sublimate, thus making working practically impossible.

Sometimes it is not possible to expose the material to be heated to a reducing atmosphere. In order to separate the furnace atmosphere from the gas filled space surrounding the heating elements, attempts have been made to build molybdenum or tungsten elements (in the form of strips, or of straight or hairpin-shaped rods) into heating chambers filled with protective gas. These chambers must be made as gas-proof as possible against the outside and the neighboring glowing part. For such a construction the amount of protective gas depends only on the degree of leakage. It is easy to ascertain the existence of big leaks by means of the gas consumed or by the pressure. A further variation of this idea led to the development of single heating elements, consisting of molybdenum or tungsten and a gas-proof ceramic tube filled with protective gas. The open end of this tube carried the electric current lead which was brazed onto the tube. The important problem, how the current is to be introduced into the tube, seems to have found a number of satisfactory solutions.

As stated above, the highest temperature suitable for molybdenum and tungsten in a protective atmosphere is exclusively determined by the speed with which these metals react with their surroundings, that is at temperatures which are very low as compared with their melting temperatures. These reactions lead to the decomposition of the conductor, until melting occurs at the thinnest spot. One has to consider two different kinds of reactions; first the reaction of the hot metal to the surrounding gas, and second the reaction to the ceramic material touching it. Traces of water vapor or oxygen in the protective gas, or of hydrocarbons, can considerably shorten the lifetime of the rods. Regarding the reaction of the metal with the ceramic material traces of iron or of free silicon dioxide can also give similar undesired deterioration. Owing to this fact, the ceramic tube must be chosen with great care.

The Stratit Heating Elements

Some years ago, another kind of high temperature heating elements were developed, as described in the United States Patents 2,105,166 and 2,193,987. These so-called Stratit heating elements consist of rods or wires of molybdenum or tungsten, which are built into vacuum-tight ceramic tubes. The rods or wires are made by the usual procedure, i.e., the

metal powder is pressed and sintered and then swaged down to the desired diameter or, if the wires are to be used, drawn down to still smaller diameters. The ceramic material has to be selected in such a manner that at least its internal layer does not react detrimentally to the metallic conductor. Therefore it is advisable to use pure alumina or beryllium oxide as an inner layer near the metal. For the outer layer sillimanite can be used advantageously. This is a silica-alumina which melts at about 1840 deg. C. (3335° F.). The working temperature is in that case about 1600 deg. C. (2900° F.).

A number of new problems appeared during the development of the Stratit heating elements. In the case of rods for high current intensity, those containing conductors of large cross sections, there is a considerable heat flow from the hot glowing part of the rod toward the rod ends. It was necessary to calculate the most favorable dimensions for the cross section of the conductor and for the material to be used at the ends of the rod, in order to reduce this heat flow to a minimum. Arrangements of this kind (i.e., reduction of cross section) are called "heat throttles." The existence of such most favorable dimensions can easily be proven by the fact that at a given current a decrease of the conductor cross section at the ends diminishes the axial heat

Fig. 2. Terminal construction of Stratit heating element.

flow losses, but increases the Joule heat in the "throttle"; on the other hand, an increase of the cross section of the end of the conductor increases the heat losses by conduction and decreases the Joule heat losses; thus there is a minimum of losses.

Another problem is the correct choice of the thermal conductivity and of the thickness of the ceramic material used. An increase of the wall thickness improves the gas-tightness, but at the same time increases the temperature drop in the ceramic wall. Hence, for a given temperature on the outer surface of the ceramic tube the temperature of the internal conductor must be increased, so that one soon reaches the point where the ceramic gets soft. A compromise between these two factors must be reached.

Mechanical Stress Conditions

The mechanical stress conditions in the ceramic have also been examined. As ceramic material has up to 10 times higher resistance against compressive stresses as compared with tensile stresses, one must consider that the tangential, radial and axial stresses in the ceramic correspond to this behavior. While these considerations apply to that part of the heating elements where the ceramic tube is completely shrunk onto the heating conductor, the ends of the rod which are sliding inside the ceramic cover must be able to expand freely. It must be noted that even if a ceramic material is used which has a thermal coefficient of expansion only about 10 per cent different from molybdenum or tungsten, axial tensile stresses arise to such an extent that breaking occurs. The expansions are about 5 mm. (3/16 in.) for rods of 50 cm. (20 in.) length at a glowing temperature of 1500 deg. C. (2700° F.), whereas the displacement of the heating elements relative to the ceramic amounts only to fractions of a millimeter. In order to be able to meet such expansion movements without deteriorating effects, the current connection between the inner heating conductor and the outside contact of the rod must be effected by suitable means, for example, a sliding contact or soft construction parts.

As the heat transmission from the heating element to the furnace proper at high temperatures takes place exclusively through radiation, the radiated heat depends on the properties of the radiating surface, characterized by the radiation constant. Experimental

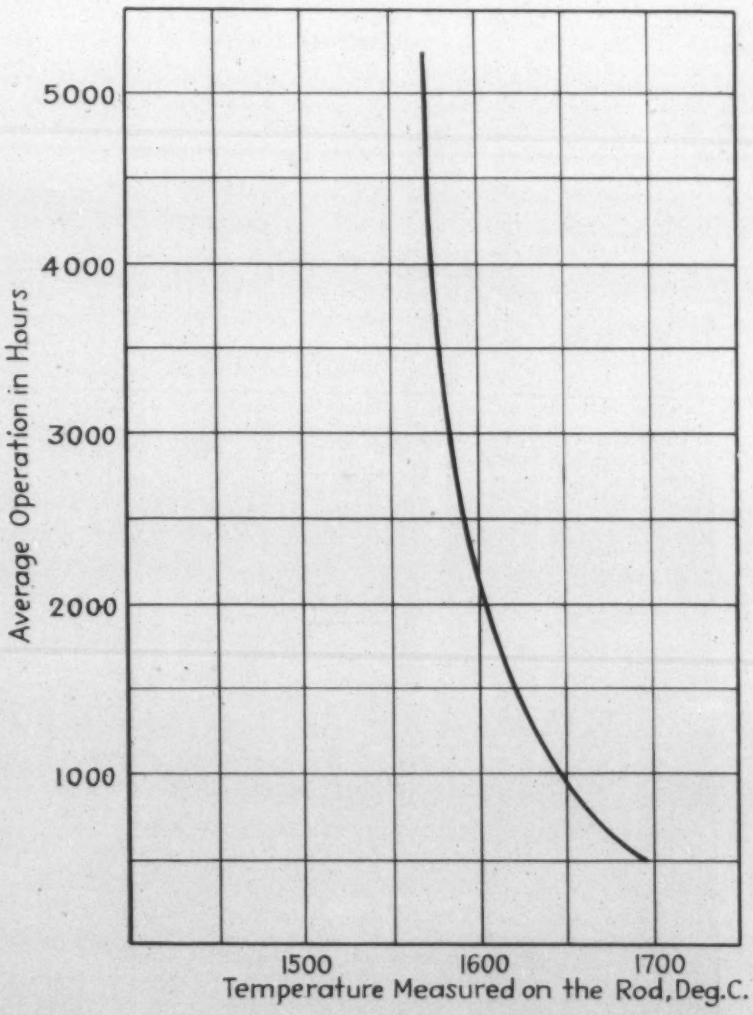


Fig. 3. Life of Stratit rods in function of temperature.

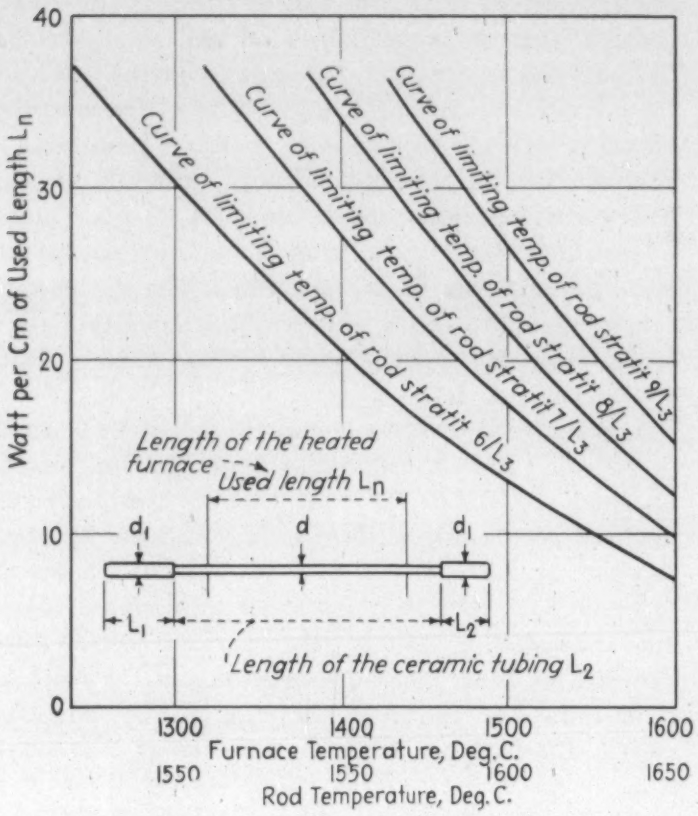


Fig. 4. Watt load of the Stratit rods per cm. of used length in function of the desired furnace temperature.

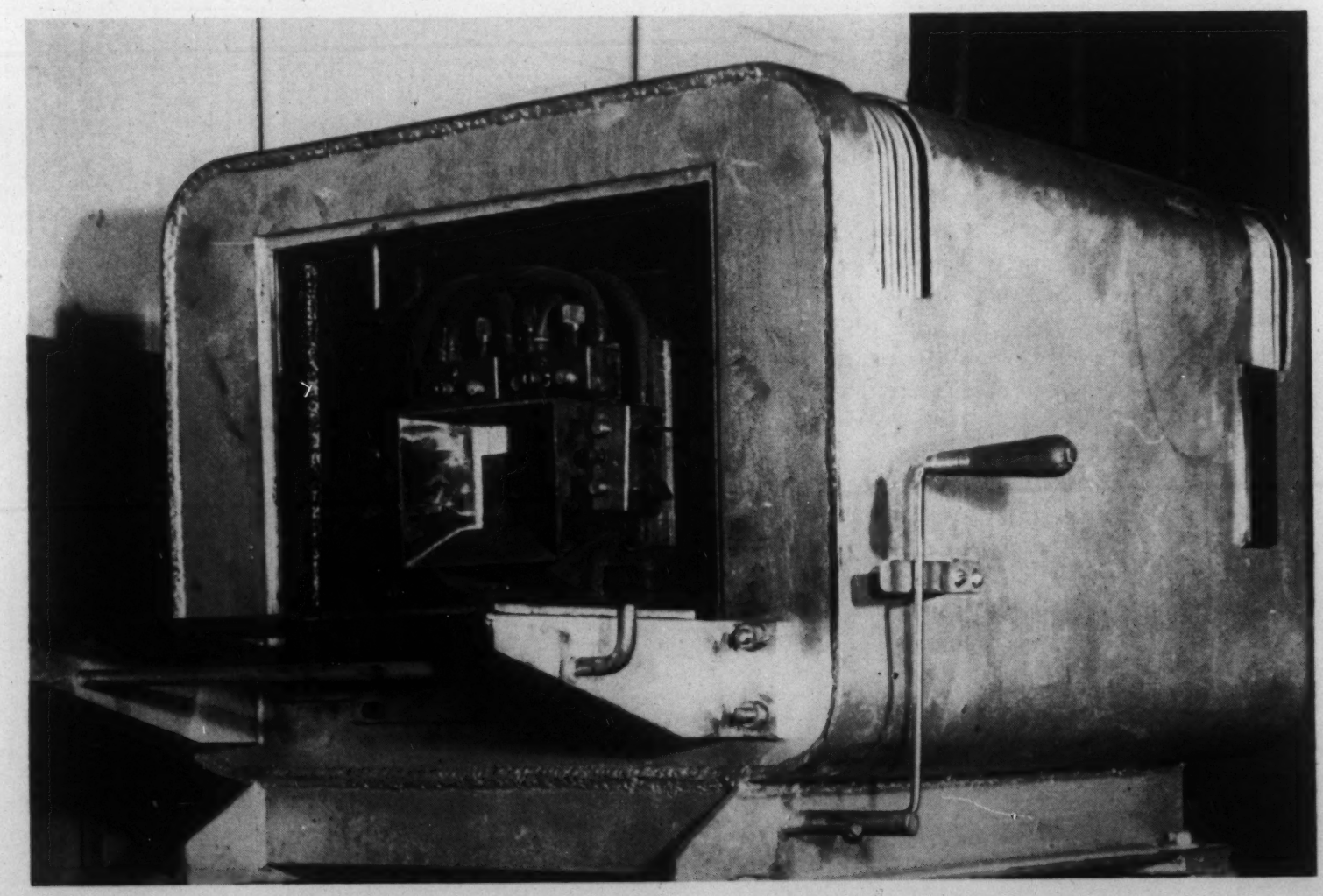
Fig. 5. A furnace equipped with Stratit heating elements.

examinations of the radiation properties of the ceramics have been made and simple methods have been developed in order to increase the "blackening" of the ceramic surface. In this way it is possible to bring the energy radiated per surface unit up to an amount which corresponds nearly to the surface of glowing carbon.

Lifetime

The lifetime of these Stratit rods is determined by the vacuum tightness of the ends of the rod, and for this purpose sealing in and brazing processes have been used which are applied in the high vacuum technique. Fig. 2 shows such a terminal construction in which (1) is the metallic conductor. Its end is split and contains a spring (2) which provides a sliding contact with the copper cap (3). This cap is soldered to the intermediate metal piece (4) which is sealed onto the ceramic sheathing (5). The rod ends are cooled by means of running water, and the cooling boxes contain the current connection. Rods have also been constructed, the ends of which are cooled by a small air cooling device.

Fig. 3 shows the lifetime of such a Stratit element plotted against its temperature. The higher the required temperature of the furnace, the higher the temperature of the heating element and the less its Watt load. This is shown by Fig. 4 which gives



W/cm used length versus furnace and element temperatures. A furnace equipped with Stratit heating elements is seen in Fig. 5.

The use of molybdenum and tungsten as heating conductors is of advantage from a regulation point of view. These metals have a positive temperature coefficient of the electric resistance, as opposed to resistance alloys, the temperature coefficient of which is often negligibly small. An increase of the voltage would increase the furnace current and thus increase the furnace temperature; but the increase in resistance diminishes the current so that the variation of the temperature is very small. In view of this "self-regulation," which occurs in the case of voltage fluctuations as well as in the case of fluctuations of the thermal load (putting in of cold material, radiation through opening the furnace door), a rough temperature control is often not necessary. A. v. Engel[1] has made a quantitative investigation about the condition of furnaces of this kind, heated by alternating current.

The behavior of the first Stratit rod constructions in different gases, like sulphur dioxide, etc., has been found to be very encouraging (in tests made by W. Trinks[2]). Later tests on the sensitiveness of these rods to quick temperature changes (as for example cold air pouring into the hot furnace) showed their resistance to such temperature variations. Heating elements used in continuous work showed lifetimes of several thousand hours. The resistance of these rods to temperature changes was also tested by switching them on and off corresponding to intermittent operations.

Cost and Operation

The cost of Stratit elements and of their operation compares very favorably with any other heating element on the market, considering particularly the fact that the Stratit elements open a new field of application, due to their high temperature range and the possibility of dispensing with a protective atmosphere. An added advantage is the fact that the replacement of a Stratit element can be accomplished within a minute's time and without interruption of the furnace operation.

Although the technical development of Stratit has been completed, the elements are not on the market because of negotiations pending regarding the respective commercial exploitation.

Summarizing, it can be predicted that within the next few years the use of heating elements made from metals with high melting points will become increasingly important.

References

[1] A. v. Engel. Bull. des Schweizerischen Elektrotechnischen Vereins, 1939, No. 6, page 162.

[2] W. Trinks. *Industrial Heating*, 1938, No. 5, page 74.

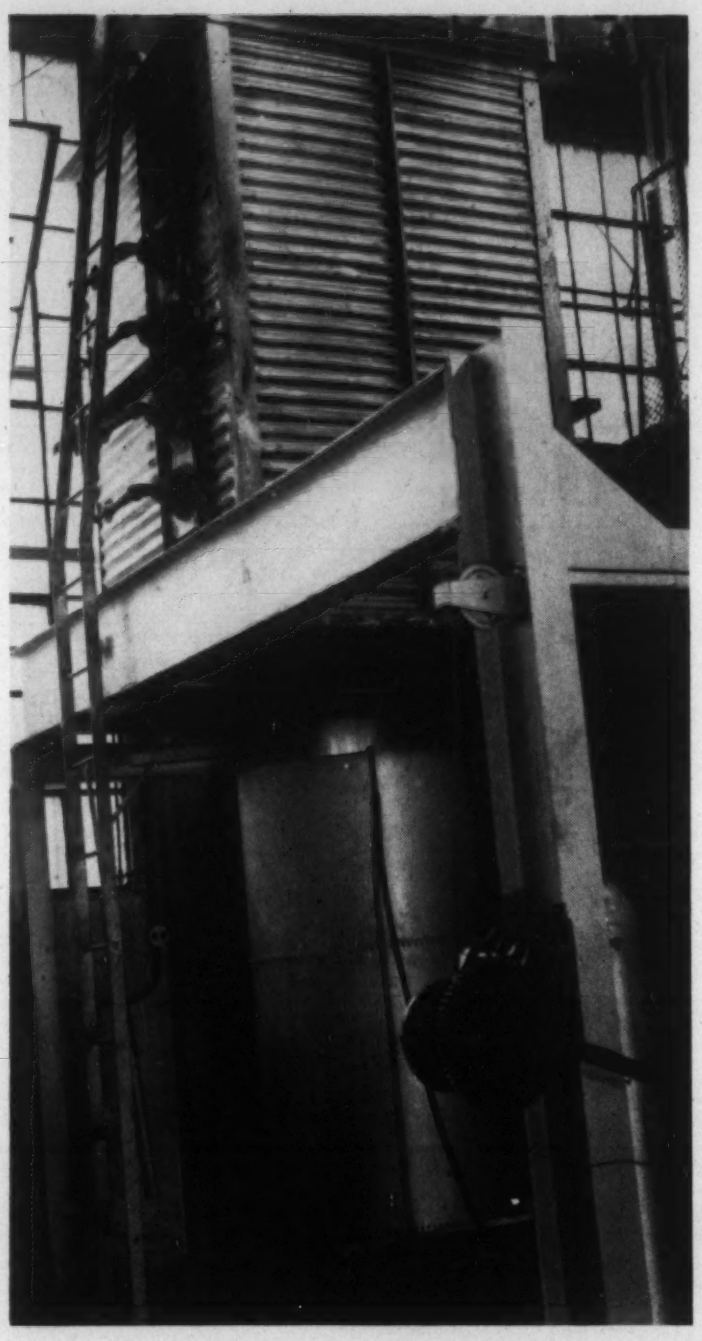
Special Heat Treating Furnace for Military and Other Parts

by HORACE C. KNERR

Consulting Met. Engineer,
President, Metlab Co., Philadelphia

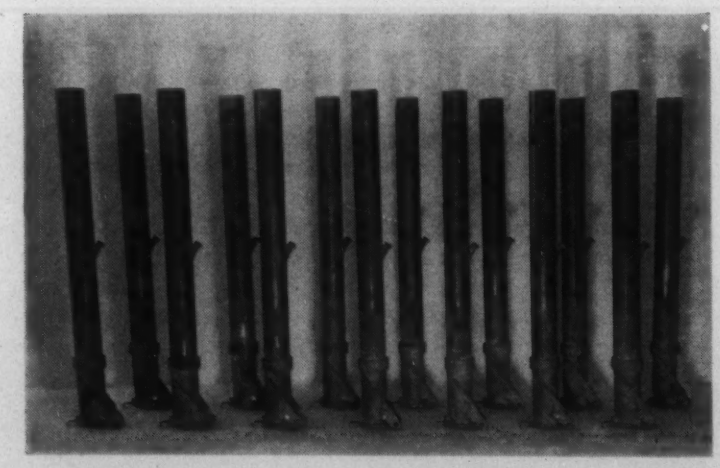
A CONSIDERABLE QUANTITY of long, slender machined parts for a military device were recently completed before it was discovered that their tensile strength and hardness would have to be increased in order to meet engineering requirements. The material was a special alloy steel requiring an oil quench from 1900 deg. F., which precluded the use of ordinary heat-treating methods and equipment because of the risk of scale, decarburization, and deformation of the accurately finished pieces. The alternative of obtaining new stock, making the parts over, heat treating in the semifinished condition and then finishing would have caused prohibitive delay in the completion of the desired equipment. The problem was solved by heat treating the parts in a new furnace of unique design recently constructed and installed by the Metlab Co. in its commercial heat-treating plant.

This furnace embodies an inverted metal retort, having a heating space about 4 ft. high, 10 in. in diameter, with a sealed door at the bottom end. Heat is applied externally by means of gas fuel; the products of combustion do not come in contact with the work. A rod of heat-resisting alloy passes through a stuffing box in the upper end of the retort and is movable up and down by means of a winch and cable so that the parts to be heat treated may be attached to a fixture on the lower end of the rod and thereby pulled up into the furnace where they hang freely suspended and without any tendency to sag under their own weight, during heating. When ready for quenching, the rod is lowered so that the charge moves directly out of the bottom of the furnace into the quenching tank beneath. This arrangement is said to insure a minimum of distortion during the heating and quenching operations, very brief exposure to the atmos-



The special vertical furnace for heat treating aircraft landing gear shock struts and other parts. In this view the charge is being quenched.

Shock struts for airplanes which were quenched vertically from the special furnace. There is a very small allowance for grinding in the inside of these parts.



phere after leaving the furnace and before entering the quenching oil, and a maximum uniformity of heating and quenching conditions.

The atmosphere of this furnace consists of completely dissociated anhydrous ammonia gas. This is fed in at the top of the retort so as to flush out the container thoroughly before the work is introduced and continues flowing during the entire cycle. This atmosphere is composed of inert nitrogen and dry hydrogen and is believed to be the most nearly ideal one which can be used in a heat-treating furnace. The nitrogen has no effect upon the material, while the hydrogen, being dry, is not decarburizing and has in fact a cleansing and deoxidizing effect. There is of course no carburizing action, such as may occur with harmful results from certain types of special furnaces using carbonaceous atmosphere.

The furnace is especially designed for the clean heat treatment of slender parts of small and medium size, such as rolls, shafts, spindles, screws, plungers, broaches, and the like, which benefit by heating and quenching in a vertical position. It is also used for the treatment of a great variety of other parts such as stampings; hardenable stainless steel parts which must withstand severe stress, wear, and corrosion; aircraft landing gear shock struts of thin tubing with a minimum allowance for final finish grinding; and so on. Some of these benefit particularly by absence of contaminating carbon, oxygen, sulphur, or other impurities in the atmosphere.

The furnace is operable up to a maximum temperature of 1950 deg. F., and will therefore accommodate many different materials including plain carbon and alloy steels, special tool steels, stainless steels, non-ferrous alloys, and in fact nearly everything except high speed steel.

The furnace is used also for bright annealing. In such work the parts are allowed to remain in the artificial atmosphere until cold; they then come out with a bright and clean finish. Quenching results in surface discoloration of the metal caused by the very brief period of exposure to the air during quenching and the effect of contact with the quenching medium. The complete elimination of scale without the necessity for packing or the use of salt baths in the heat-treating process, and without exposure to the air which accompanies quenching from furnaces of the ordinary crucible or pit type has many advantageous applications. Where very accurate tolerances govern, it is of course desirable to provide for final grinding to compensate for the effect of volumetric changes and the internal stresses unavoidable in the heating and cooling operations.

The accompanying illustrations show the furnace and some typical parts heat treated in it.

Nickel thimbles for an electrical device which have been bright annealed in the same furnace.

(*Continued from page 21*)
improved technique that will be recorded in the engineering journals of 1941, but the environment of 1940 has not been conducive to a good rate of real worldwide progress, nor is it likely that 1941 will be much of an improvement.

We have a new year that will be a busy one. It will be a happy one for us and our friends abroad if past metallurgical progress and present manufacturing ability prove sufficient to check decisively, and clearly to predict the relatively early defeat of, the dictators.

After this job of curbing the aggressors is attended to and there arises the further job of meeting the changed conditions and struggling through the next New Deal depression, the degree of happiness of those years will strongly depend on the degree to which metallurgical engineering lays in 1941 those further foundations for continued future progress. Most of those who read this will outlive both the foreign dictators and the politicians of the present administration. We hope that our pages will record in 1941 metallurgical information of value in solving the long range problems as well as those more immediate ones of defense.—H.W.G.

Light Weight Rolling Stock

In its Passenger Progress Number *The Railway Age* for Nov. 16, published a most interesting table listing the passenger coaches and body units of articulated trains in which the new structural materials and new methods of fabrication have been used to reduce weight. It covers the years 1931 to 1940 inclusive for units completed and on order.

The materials which are listed include "high tensile" steel (mild-alloy steels) stainless steel, aluminum alloy, "high tensile" and stainless, "high tensile" and aluminum, carbon steel, and "alloy" steel.

An analysis of these data shows that there are 1874 units or cars involved. Of these 957 or 51.06 per cent were constructed of the mild-alloy types; 371 or 19.79 per cent were built of stainless steel, and 244 or 13.02 per cent of the aluminum alloys. Carbon steel went into 175 units or 9.33 per cent, while the cars of "high tensile" steel frames with stainless steel sheathing made up 120 units or 6.40 per cent.

With public attention fixed by advertising on the stainless or streamlined trains, the use of the low-alloy, high strength steels has not been so generally publicized. The fact that over half of the cars made or on order have been constructed of the mild-alloy types to reduce weight is of distinct interest.

A still broader use of these steels is expected—not only for units of the type here analyzed, but also when these materials are more extensively incorporated in box, hopper and other freight units, a field in which pay load is a very important factor.—E. F. C.

Manganese

A reassuring statement of the American Iron and Steel Institute recently is that the war has not curtailed the supplies of manganese despite the fact that more than 96 per cent of the manganese consumed by the American steel industry in the last 12 years has come from abroad. A further statement is that, at peak operations, nearly 540,000 net tons per year of metallic manganese is consumed. This is based on 13 lbs. of manganese to the net ton of steel.

This means about 675,000 tons of 80 per cent ferromanganese and over 1,000,000 tons of 50 per cent metallurgical manganese ore annually—a very large order to fill.

But the suppliers of both ferromanganese and the ore are nearly meeting the demands. Imports of ore are at the rate of over 1,386,000 tons yearly and the output plus imports of ferromanganese total over 500,000 tons annually. While the latter is somewhat below the theoretical needs, the situation is not alarming. The greater use of spiegeleisen, improvements in practice and substitutes for manganese are mitigating factors. And the reserves of ore brought in for stock are said to be ample for nearly two years' supply.—E. F. C.

letter

TO THE EDITOR

The Iron Powder Situation

To the Editor: I have read in your September, 1940, issue, page 288, an article on "The Iron Powder Situation."

There are many grounds on which we might disagree with the author of this article, such as his reference to stock salesmen carrying about bottles of sponge iron, for everyone knows the New Deal has made things such that only the mentally afflicted would dare sell shares of stock in some new enterprise. He's thinking of a former age when men had freedom to invent, devise and make available new

and better articles and enterprises for the common benefit, even though they might chance to make a few dollars from their speculations.

However, the important thing he brings up is sponge iron. He seems to labor under the belief that, since we are cut off from Sweden, we must devise other means for obtaining iron powder, holding that no one in the United States can duplicate the Swedish product. Accordingly, I wish to announce through your magazine that we will, if sufficient business is at hand, complete a plant to produce not the equivalent of Swedish sponge iron but to furnish a product superior in every way.

Our ores are at least the full equivalent of Swedish ores, our charcoal is just as good and our processing is advanced over Swedish practice. Only two patents are issued, to date —Nos. 1,829,124, and 1,987,952. Others are pending and in preparation. Furthermore, we will furnish sponge iron in any particle size desired, from 40 mesh down to micron sizes, if there be any present demand for the ultra fine product. Logically we will charge a higher price for the finer material, but not any very great advance over the price for the coarser material.

If those interested will furnish us specifications and prices they are willing to pay and will extend contracts of reasonable duration, we will enter into contract to furnish a reasonable supply. We haven't the least fear of the war ending and bringing in Swedish material to upset our market. If we can have the business during this war, or for a reasonable period, we will take chances on competition after that.

I believe it was in 1930 that I chanced to stay at the Stevens Hotel in Chicago and visited the National Metal Congress and the exhibits. I had a piece of blue hematite ore from some of my claims. The Swedish people had a table piled high with their pretty blue hematite. I approached the attendant—a big husky Swede who had not yet thoroughly mastered American accent, although he handled the language very well—and I showed him my chunk of ore, a piece about as large as the doubled fist. He asked me where I got it and I told him from Utah. He laughed good-naturedly and told me I was playing jokes on him and that I had taken it from his table. I had a difficult time persuading him that we had considerable tonnage of that ore. You couldn't tell my ore from his by laying the two kinds side by side.

Incidentally, that ore I exhibited assayed 69 per cent Fe, a fraction of one per cent manganese and virtually no gangue minerals. The phosphorus and sulphur were mere traces.

Now, we chance to have other ores which carry sufficient gold to help pay the costs of mining and crushing. I have a mill wherein we can crush, grind the ore and amalgamate it for recovery of the free gold. If I can get sufficient orders I will install one of my retorts and reduce that highly pure iron oxide with charcoal to a high-grade sponge iron, and I can afford to make some attractive prices to get the orders if extended RIGHT NOW.

LEROY A. WILSON.

P. O. Box 14,
Veyo, Utah

Comment by Mr. Fellows

To the Editor: Thank you for the opportunity of replying to Mr. Wilson's delightful letter.

I should like to limit my remarks to noting that Mr. Wilson's third paragraph shows he has read my article to a conclusion which was not intended. I did not mean to hold "no one in the United States can duplicate the Swedish product." On the contrary, it was stated "Swedish sponge iron may already have fulfilled its destiny in American powder metallurgy," and there is also mention of the "folly to attempt to bring out an iron which Swedish sponge could drive off the market if it were to return as a result of cessation of hostilities abroad."

From this unwarranted, or at least not intended, conclusion, Mr. Wilson has thus embarked on the subject which forms the bulk of his communication. One will there note five "ifs" concerning his business plans. That somehow seems to be just about the right number for that hypothetical person with the capacious vest pockets whom I visualized.

ALBERT T. FELLOWS.

A Poem

To the Editor: During the recent heat wave, our minds wandered somewhat astray. As our lips were wont to babble continually, some one jotted down the enclosed verses. They represent the product of mass deterioration of the intellect and should be regarded as such. Thinking perhaps you might be interested in one result of Nature's eternal battle against Man, we are sending you the evidence to use as you see fit.

J. TUCKER MACKENZIE

Research Laboratory
U. S. Steel Corp.
Kearny, N. J.

The verses, signed by J.T.M. & Staff of the Research Laboratory, follow:

EFFECT OF TEMPERATURE ON THE MINDS OF METALLURGICAL ENGINEERS

Here, gentlemen, is some advice.
To comprehend, please read it twice.
If you would work on fender stock,
You won't have time to watch the clock.

Just pick some strips both long and thin
And stamp them well, don't mind the din.
Then polish hard, to shine the steel.
If it won't glisten, try the wheel.

A Rockwell here, a Rockwell there.
It may be hard, so best beware.
A box anneal or normalize,
Then cold reduce and spheroidize.

Another polish, smooth as glass.
It must be good, or it won't pass.
A Rockwell there, a Rockwell here.
A shotgun pattern!—!!#%&$—Oh! Dear!

Cut up the strips and mount them fast,
Then to the wheels, right through the last.
A microscope will solve your woes,
If your technique's as good as Joe's.*

Now, is the grain size coarse or fine,
The carbides scattered or in line?
Next, just how dirty is the steel?
Be sure your pictures, all, reveal.

It's finished, though it took a year.
You should go out and have a beer.
But, write it up and turn it in.
Don't heave a sigh, just start "agin."

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* Joe Vilella

(Mechanical difficulties prevented earlier use of this good poem —more apropos in August when it was written—The Editor.)

METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

Alloys
Applications
Designs
People
Plants
Societies

Heat Treating and Case Hardening

Before plunging into this rapid-fire review of some recently-announced developments among furnaces for heat treating, case hardening, age hardening, etc.—developments that incidentally emphasize the expanding influence of the engineer in the heat treating field—we can't refrain from paying a tiny tribute to the undiminished and perennially needed artistry of the tool and die hardener.

Independent, intelligent, a master craftsman with an intimate knowledge of the vagaries of steel that sometimes surpasses the understanding of engineer, metallurgist and steelmaker alike, the hardener today has a vital and expensive trust. On his sensitive hands, practiced eyes and patient care depends the performance of countless tools, dies and steel parts essential to the rapid rearming of this country. May his engineer colleagues continue to provide him with the most efficient equipment modern knowledge can devise!

Ammonia in Metal Treating

One of the most widely-used of modern aids to hardening, tempering, annealing, nitriding, dry cyaniding, (even welding), etc. is anhydrous ammonia. Its many applications, furnace equipment for handling it, and cost and performance data are interestingly presented in a new 44-page booklet of *Mathieson Alkali Works,* New York.

Previously uncracked ammonia is employed for nitriding suitable alloy steel and surface-hardening stainless steels; mixed with carburizing gases, it makes possible "dry cyaniding" or simultaneous gas carburizing and nitriding; injected into charcoal generator gas, it contributes to the success of the commercial bright hardening process known as "hydryzing"; and previously cracked or dissociated, it provides hydrogen-nitrogen atmospheres whose applications for bright annealing ferrous and non-ferrous metals, for bright hardening of steels, and for brazing are steadily increasing.

Taken separately, most of the processes described in the booklet are not new, but the assumption of a new viewpoint in examining these operations should challenge the interest of many metallurgical engineers.

Convected-Air Furnace for Aluminum and Magnesium Alloys

A new convected-air furnace built by *Despatch Oven Co.,* Minneapolis, Minn. is described as in regular use for the heat treatment of aluminum and other non-ferrous alloy castings. It is claimed to reduce the total time of the processing cycle and to provide temperature uniformity of ±5 deg. F. throughout the furnace chamber when operating at 950 deg. F.

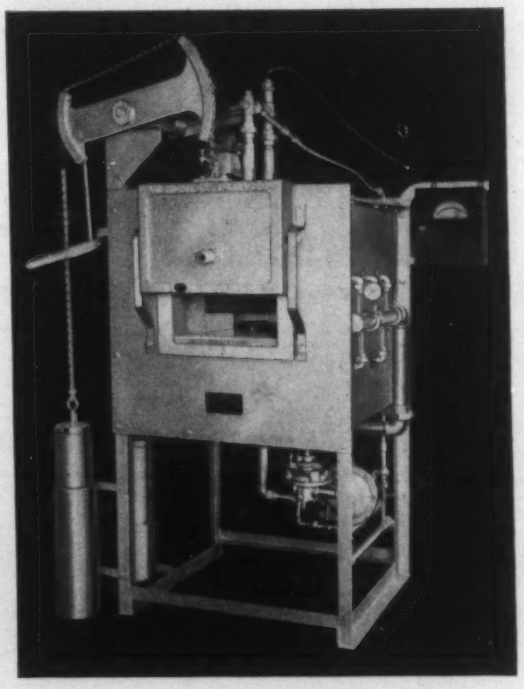
Uniformity is a direct result of the use of oversized, large-volume, high static pressure fans. Air velocity through the furnace exceeds 20 mi. per hr. and is said to assure rapid and uniform heat treatment. A unique feature is a Despatch-designed quenching system that makes possible quenching in 18 to 20 seconds instead of 40 seconds or so formerly used.

Illustrated is an application of the furnace for the age-hardening of 1200-lb. charges of aluminum alloy castings; the work is loaded in baskets pushed into the furnace, processed for 18 hrs. and quenched in boiling water. The electric heating system for this furnace consists of an open-coil, low-gradient 100-kw. heater, but the furnaces can also be built with gas-heating systems.

Gas Atmosphere Furnace

A new oven type of furnace, provided with a bell of heat-resisting alloy that closes down on the work during treatment, has been developed by *American Gas Furnace Co.,* Elizabeth, N. J. The furnace (illustrated) is particularly useful for small-scale heat treatment under definite temperature and atmosphere control.

The bell can be quickly and easily raised by the door-lifting mechanism. Uniformity is said to be excellent because the bell is totally enclosed and heated by burners firing both above and below from the sides. Carburizing, nitriding, Ni-Carbing, clean hardening, bright annealing and brazing can all be done in this furnace.



Novel Electric Furnace

An interesting electric furnace for heating magnet steel both for forging and for hardening has just been installed by the Connecticut Telephone & Electric Corp., 100 Brittania St., Meriden, Conn.

The furnace—a 20-kw. controlled-atmosphere unit made by *American Electric Furnace Co.,* Boston, Mass.—is capable of hardening 120 magnets per hr. while about 80 pieces of stock are being heated for forging into the correct magnet form. The horseshoe magnets are hardened continuously with the aid of a simple pusher apparatus. After reaching the hardening temperature, the magnets drop through a slot in the rear wall of the furnace into a quenching tank and are automatically picked up by a conveyor belt which takes them up out of the quench and drops them into a basket.

The high quality magnets so produced are used in telephone ringer magnetos.

(Continued on page 56)

Electric Gas-Carburizing Furnace

A new gas-carburizing electric furnace for case-hardening steel parts has been announced by *General Electric Co.*, Schenectady, N. Y. The furnace is said to provide all the cost- and time-saving advantages of gas carburizing in general plus the close control of temperatures and operating schedules characteristic of electric furnaces.

The new furnace employs propane as the carburizing gas [for detailed description of a gas-fired propane-carburizing furnace, read "Gas Carburizing with Pure Propane" in our Jan. 1939 issue, p. 13], the amount of active carbon in the furnace being controlled by measured regulation of the flow

of gas. Rapid circulation of the gas is said to assume quick heating and uniform temperature distribution.

DuPont X-ray Film—A Correction

In our December issue, on page 778, we described a "fast" X-ray film in terms that may be misleading to many readers. The *DuPont Film Manufacturing Corp.*, 9 Rockefeller Plaza, New York, manufacturers of the film, have never claimed it *in general* to "save 30 to 40 per cent on exposure time as compared with films heretofore available" (as we reported) but say more accurately that this "DuPont Industrial X-Ray Film" is the most sensitive available for recording the output of a tube employing a high kilovolt peak.

In industrial X-ray work, there is a trend toward the use of more penetrating rays for examining thick metal parts. Such rays are produced by increasing the kilovoltage across the tube to very high values, and it is in high-voltage work of this nature that the greater speed of this film is applicable.

● A new rotary shear that cuts through 2-in. mild steel plate and which is claimed to give the fastest cutting speeds ever available in a shear has been developed by *Quickwork-Whiting Div. of Whiting Corp.*, Harvey, Ill.

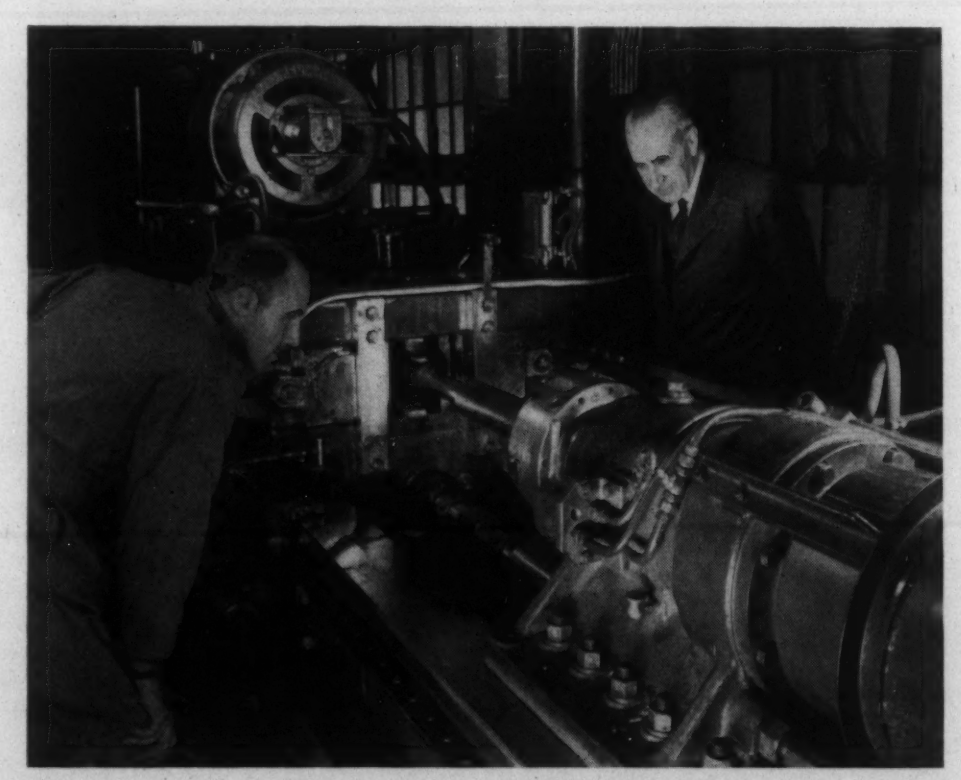
New Tiny Air Grinder

Originally intended as a die grinder for tool room and bench work, a new "baby" air grinder of *Ingersoll-Rand Co.*, Phillipsburg, N. J., is now being used by industry at large for light grinding jobs wherever metal must be removed from places that would otherwise be hard to reach.

This tool (size 00) weighs only 1¼ lbs., operates at 20,000 r.p.m. at 90 lbs. pressure, and is built to take 1½-in. diam. organic bonded or 1¼-in. diam. vitrified wheels. Various sizes of collets to take mandrel-mounted grinding wheels or small twist drills are also available.

● Of interest to foundry engineers are 2 new coating products of *Tamms Silica Co.*, 228 N. La Salle St., Chicago: "Patternseal," for sealing and coating match plates, core boxes, etc. to prevent moisture penetration; and "Metaline," a metal-like liquid for coating and sealing wax fillets and gates before applying Patternseal.

New Tube-Shaping Machine for Aircraft Parts



Aircraft landing gear struts, aileron torque tubes and other components are being produced at *Steel & Tubes Div. of Republic Steel Corp.*, Cleveland, Ohio, on a new machine that automatically shapes tubular products to practically any contour that could be machined from solid stock on a lathe.

The 65-ft.-long machine was developed by C. L. Dewey (right) and his son Sydney, and is the only one of its kind built so far. The tubing is shaped by rolls in a moving carriage on which a motor is mounted, and the action of which is determined by a cam parallel to the tube (on the right). The wall thickness is controlled by working the tube under variable tension load.

Although now used exclusively for aircraft parts, the machine has potential application for tubular products for a variety of purposes, it is said.

Reclaiming Steel Rolling Mill Equipment by Welding

The spindles, crabs and coupling boxes on rolling mills are subjected to extremely severe service, and replacement costs because of rapid wear are considerable. However, by the use of suitable welding materials even badly worn pieces can be repaired and reclaimed with the assurance that the additional service obtained will offset the expense and even provide an actual saving.

The following procedure, developed in one of the larger Eastern steel plants, has resulted in service life several times longer than that ordinarily obtained from new parts. The steels used for spindles and crabs are usually carbon steel ranging from 0.45 to 0.55 per cent carbon and the customary 12-14 per cent manganese, or Hadfield, steel.

In the case of carbon steel parts, all spalled or loose material (often as much as 1½ in.) is removed by a cutting torch or by chipping and grinding. The piece is then preheated to 400-500 deg. F. and a carbon steel rod of comparable analysis is used to make the initial deposit to within ½ in. of the finished surface.

Each bead must be peened as applied. The additional material needed to complete the build-up is applied with electrodes of Amsco nickel-manganese steel, containing 3.5-4 per cent nickel, 14 manganese and 0.75-0.90 carbon—available from *American Manganese Steel Div., American Brake Shoe & Foundry Co.*, Chicago Heights, Ill. Each bead of the nickel-manganese deposit should also be entirely peened and any high spots should be removed with a hand grinder. To prevent spalling in service, a dove tail or groove, ¾ in. wide and ½ in. deep, should be provided at the back of each pod.

If the part is of Hadfield steel, the spalled material is removed by grinding and preheat temperatures must be limited to 300 deg. F. Heating, however, does not adversely affect nickel-manganese steel, and the entire build-up is then made with nickel-manganese steel electrodes as described.

The procedure for reclaiming coupling boxes is similar except that the initial build-up material is always nickel-manganese steel. Because peening is difficult, the final ¼ in. to reach finished dimension should be deposited with a hardfacing welding rod such as Amsco Economy Hardfaced electrodes, which give a surface of 450-500 Brinell, it is said.

New Plants and Expansions

Under the impetus of defense orders, metallurgical engineering plants are expanding and a-building at a rate that defies complete recording. Some of the "new-facilities" developments that have recently come to our attention are reviewed herewith.

Worthington Pump & Machinery Corp., Harrison, N. J., is constructing a 175-ft. x 100-ft. addition to its plant. *Wells Mfg. Corp.*, Three Rivers, Mich., have moved into a new modern 1-story factory with increased facilities for making metal-cutting band saws. A $3,000,000 expansion program is now being carried out by *Timken Roller Bearing Co.* at its Canton, Gambrinus, Columbus and Mt. Vernon, Ohio, plants.

Crobalt, Inc., Detroit, announces the completion of a new plant at Ann Arbor, Mich., for the expanded manufacture of Crobalt, a cutting alloy containing tungsten, chromium and cobalt. *The National Advisory Committee for Aeronautics* has selected the Municipal Airport at Cleveland as the site for the Government's $8,500,000 aircraft engine research laboratory.

● A research program on the spot welding of magnesium and aluminum alloys has been organized at Rensselaer Polytechnic Institute by the *Welding Research Committee of Engineering Foundation,* the work being financed by government and service air bureaus and the Aluminum Co. of America.

Byers to Produce Alloy Steel

The 76-yr. old *A. M. Byers Co.*, long a leader in the manufacture of wrought iron, will soon enlarge its activities to include the production of a broad line of alloy steels, including stainless.

Production will begin within 6 months. An addition will be built to the company's Ambridge, Pa. plant, and will be used as a melt shop for new electric furnace equipment to be installed. Equipment for heating and rolling alloys already exists within the plant. Initial products will be billets and bars for alloy steel fabricators.

Promotion of wrought iron in present markets and the development of new uses for wrought iron will in no way be diminished by the new alloy steel program, the company states.

● A new type of Monel metal called "KR" Monel by its producers, the *International Nickel Co., Inc.*, 67 Wall St., New York, is *both* free-machining and hardenable by heat treatment, in addition to being strong and corrosion-resistant.

New Engineering Bronze

A new addition to the series of engineering bronzes produced by *Ampco Metal, Inc.*, Milwaukee, Wis., is Ampco Metal 20-13—really a modification of grade 20 by a special heat treatment. Outstanding characteristics of the new grade are said to be its unusual combination of good elongation (about 10 per cent) and high Brinell hardness (about 200), and its resistance to both corrosion and abrasion.

Heat treatment is such as to produce a beta matrix carrying primary alpha crystals. The bearing characteristics of the new grade are described as unusually good, even where lubrication is doubtful. It is recommended by the manufacturer for bushings and bearings on hardened steel or for heavy duty work; for cylinder liners, plungers and pump parts including those handling corrosive liquids.

● A lubricated plug valve made of special alloy steel, with plug and interior faces hard-surfaced, has been developed by *Merco Nordstrom Valve Co.*, 400 Lexington Ave., Pittsburgh. Capable of handling a working pressure of 7500 lbs., it is believed to be the heaviest duty plug valve ever manufactured.

Weld Controller

To eliminate the need for skill in timing manually-timed welds and to aid in attaining uniformity of welds, a new weld timer-contactor to be used with any 15 to 35 kva. manually or mechanically-timed spot welder is announced by *Weltronic Corp.*, 3071 East Outer Drive, Detroit.

Available for 220, 440 or 550 welding voltages and for 25, 40, 50 or 60 cycles frequency, the new unit (model 108-53) is adjustable over a range of timing of 2 to 30 cycles. Two control knobs provide for close adjustment. Contacts are quickly removable for replacement, and the entire unit can be serviced without specially skilled help.

● Murex "Alternex" is the name of a new covered electrode for manual arc welding developed by *Metal & Thermit Corp.*, 120 Broadway, New York, for use with transformer type a.c. welding equipment.

Radiographic Inspection on Wheels

To check the perfection of castings and welded parts that go into products of the Erie Works of General Electric Co., the portable industrial equipment shown here is used. The equipment, a *General Electric X-Ray Corp.* unit, is on a mobile truck-type mounting, and is rated at 75 to 220 kilivolts peak at 10 milliamperes.

The apparatus is described as completely shockproof, with all high-voltage equipment, including the X-ray tube and transformer, oil-immersed in a grounded metal case. The machine weighs 7000 lbs., and its rays will penetrate about 3½ in. of steel.

Selection-Chart for Die Casting Alloys

Comparative Ratings from Specific Standpoints

No single die casting alloy or type of alloy rates above all others on all scores. If any one did, of course, there would be no reason for using the others at all unless some scarcity of its ingredients made it unavailable in the quantities required. Since this is true, the engineer and designer, in selecting the alloy to be used, should first list those properties that the alloy *must* possess and those conditions that it *must* meet, and then consider which of the alloys affords the best balance of advantages under these heads.

For this purpose, the accompanying table, prepared by die casting authorities familiar with the use of all the alloys listed, is exceedingly helpful, because it rates each of the alloy types commonly used for die castings in their respective orders of merit under each of 21 headings. These headings include not only mechanical properties and physical constants but, what is often more important from certain standpoints, the relative casting properties and the cost of the dies and of the casting itself.

In each case, the numeral 1 indicates the alloy with the highest rating (that is, the "1" alloy is generally "most desirable" in each respect) and numeral 4 the lowest. In each instance where there is little difference in merit, the ratings are made equal and, of course, under this heading there is no ground for choosing one alloy over another.

Although the zinc alloys do not rate highest under any of the mechanical and physical properties listed, they rank first in extent of use. Contributing to their wide use, of course, is the fact that they are generally rated highest in casting characteristics and lowest in cost per casting and in die cost. The zinc alloys are second only to the brasses in mechanical properties. Where light weight with satisfactory mechanical properties is desired, the aluminum and magnesium alloys should always be considered. It is interesting that the brass die castings rank highest in cost and are lowest in extent of use, showing how commercial considerations often offset high rating under mechanical properties.

Selection Factor		Aluminum Alloys A.S.T.M. Nos. 5, 7, 12	Brass	Magnesium Alloys A.S.T.M. Nos. 12 and 13	Zinc Alloys A.S.T.M. Nos. 21, 23, 25
Mechanical Properties	Tensile Strength	3	1 (strongest)	3	2
	Impact Strength	3	1 (toughest)	3	2
	Elongation	4	1 (most ductile)	3	2
	Dimensional Stability	2	1 (most stable)	3	3 [a]
	Resistance to Cold Flow	2	1 (most resistant)	2	3
	Brinell Hardness	3	1 (hardest)	3	2
Physical Constants	Electrical Conductivity	1 (highest)	2	3	2
	Thermal Conductivity	1 (highest)	2	4	3
	Melting Point	2	1 (highest)	2	3
	Weight, per cu. in.	2	4	1 (lightest)	3
Casting Characteristics	Ease, Speed of Casting	2	3	2	1 (easiest)
	Maximum Feasible Size	1 (largest feasible)	2	1 (largest feasible)	1 (largest feasible)
	Complexity of Shape	1 (greatest possible)	2	1 (greatest possible)	1 (greatest possible)
	Dimensional Accuracy	2	3	2	1 (most accurate)
	Minimum Section Thickness	2	3	2	1 (thinnest)
	Surface Smoothness	2	3	2	1 (smoothest)
Cost	Die Cost [b]	2	3	2	1 (lowest)
	Production Cost	2	3	2	1 (lowest)
	Machining Cost	2	3	1 (lowest)	1 (lowest)
	Finishing Cost [c]	3	2	3	1 (lowest)
	Cost per Piece [d]	2	3	2	1 (lowest)
Extent of Use at Present		2	4	3	1 (most used)

[a] Through the use of a low temperature annealing treatment, Alloy No. 23 can be made virtually stable in dimensions.
[b] Dies for casting the low melting point alloys are least expensive and have longest life.
[c] Includes polishing and buffing expense as well as ease of applying all types of commercial finishes, both electrodeposited and organic.
[d] Based on die, material and fuel costs, production speed and machining and finishing costs.

Improved Metal-Cutting Alloy

Haynes Stellite Co., Kokomo, Ind.. is now supplying instead of its old grade of Haynes Stellite J-Metal a new cobalt-chromium-tungsten alloy for tools, known as Haynes Stellite Star J-Metal.

The new cutting alloy is said to be a substantial improvement over the old with respect to tool life between grinds, and is recommended by the company for all machining operations now performed with the original J-Metal tools on cast iron, steel or other materials. Operating conditions and grinding practice are the same with the new Star J-Metal tools as with the old.

The new alloy is now available in all of its manufacturers' standard and special blade designs and sizes, in the form of standard welded-tip tools and in many special tool designs—all prices remaining the same as for the original J-Metal tools.

Reconditioning Worn Parts

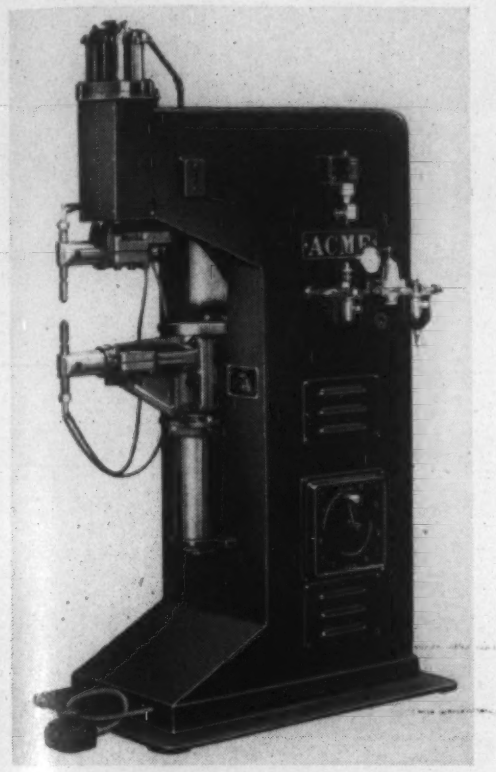
Many locomotive parts that would normally be scrapped because of excessive wear are being reconditioned and reclaimed by metal-spraying with stainless steel and remachining to size in the shops of a midwestern railroad, reports *Carboloy Co., Inc.,* 1036 Book Bldg., Detroit.

In practice, "18 and 8" stainless steel is metal-sprayed onto the grit-blasted surfaces to a depth of 1/64-1/32 in. on each side in excess of the required finished-part-size, using the wire process.

To obtain the fine finish desired, the stainless-metallized parts are turned at high speeds—200 to 450 ft. per min. with fine cuts and a slow feed, using Carboloy cemented carbide tools. On parts that cannot be turned the surfaces are finished by grinding from the rough.

Press Type Spot Welders

Built in 30, 40, 50 and 75 kva. capacities and designed to meet the demand for an inexpensive high-production, sturdy, direct-action air-operated press type spot welder, the new type PT1 welders of *Acme Electric Welder Co.*, Huntington Park, Cal. are said to have a variety of uses in both spot and light projection welding on steel and alloy parts.



Welded steel bases rigidly reinforced; reversible, accurately-sized double end horns; advanced transformer design and construction; positive-lock radial-type heat regulator; and complete water cooling hook-up are among the features and advantages claimed for the new welders. All welders are standard for 220 volt, 60 cycle alternating current, but welders for voltages up to 550 can also be supplied.

A larger and heavier model (PT2), designed for welding heavier gages or where an especially long throat reach is desired, is also available—in 100, 125 and 150 kva. capacities.

Meetings and Expositions

AMERICAN SOCIETY OF CIVIL ENGINEERS, annual meeting. New York, Jan. 15-18, 1941.

AMERICAN SOCIETY OF HEATING & VENTILATING ENGINEERS, annual meeting. Kansas City, Mo., Jan. 27-29, 1941.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, winter meeting. Philadelphia, Jan. 27-31, 1941.

INSTITUTE OF AERONAUTICAL SCIENCES, annual meeting. New York, Jan. 29-31, 1941.

TECHNICAL ASSOCIATION OF THE PULP & PAPER INDUSTRY, annual meeting. New York, Feb. 17-20, 1941.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, annual meeting. New York, Feb. 17-21, 1941.

New Tough Tool Steel

A medium-carbon manganese-molybdenum steel (773 tool steel) has been added to the list of tool steels of *Jessop Steel Co.*, 546 Green St., Washington, Pa.

The new steel is said to possess unusual toughness, and to be ideally suited therefore for applications requiring exceptional toughness in thin sections, such as step-down dies, spatulas, putty knives, etc., as well as for general tools, dies, punches, chisels and so forth. A ¼-in. section hardened and drawn to 58 Rockwell C will take a permanent set without cracking or bending, according to the manufacturer.

New Posts and Offices for Metallurgical Engineers

T. G. Stover has been promoted to purchasing agent in charge of outside plant material and non-ferrous metals for Western Electric Co., Inc., New York. . . . *N. K. Koebel,* formerly of Eastman Kodak Co., is now research director for Lindberg Engineering Co., Chicago. . . . *George R. Sylvester,* formerly chief engineer of Allied Engineering Co., has been appointed technical advisor for Ajax Electric Co., Inc. . . .

Albert R. Stargardter has recently been made chief metallurgist of Eastern Rolling Mill Co., Baltimore, Md. . . . *R. E. Zimmerman,* vice-president of United States Steel Corp. is the new president of the American Standards Assoc. . . . *Francis C. Frary,* director of research of the Aluminum Co. of America, has been elected president of the American Institute of Chemical Engineers. . . . *Otto Kessler* has joined the Foote Mineral Co., Philadelphia, as chemical engineer.

● The increasingly popular gear steel, S.A.E. 4640 (nickel-molybdenum type), is now carried in stock "for immediate shipment" by *Jos. T. Ryerson & Son, Inc.*, Chicago, in hot-rolled annealed rounds from 1 in. to 5 in. diam.

New Bearing Bronze

A new bearing bronze, designed for a wide range of bearing and seal applications, and produced by a method said to assure uniform and extremely fine dispersion of lead in the structure, has been developed by *Monarch Alloys Co.*, Ravenna, Ohio.

Known as Monarch Metal, the new bronze is alloyed in various high-lead combinations, the process being fundamentally one of melting out of contact with furnace gases or the atmosphere, and water-cooling the solidifying metal. It is said that the resulting structure is free of hard, abrasive tin and lead oxides and that the "better nodulation" of the lead keeps it from flowing under heat.

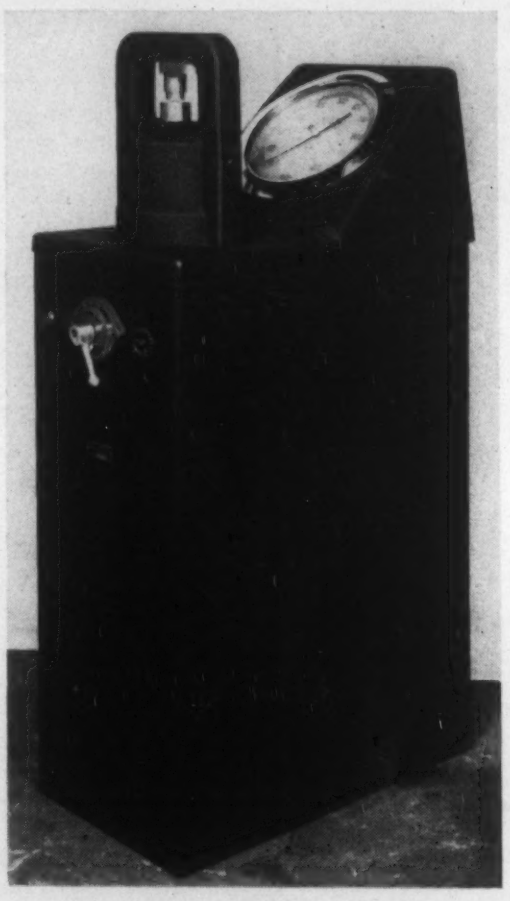
According to the manufacturer, Monarch Metal bearings will not seize or gall their shafts, even in the event of lubrication failure. Hardness and compression resistance are said to be remarkably high for a high-lead bronze. The new bearings are also claimed to be easier and safer to run in when new, no graphite solution being necessary with them.

The process is believed to be applicable to other non-ferrous bearing alloys (aluminum, for example) with similar improvement in their bearing properties.

Spectrograph Specimen Press

A new specimen-briquetting press for preparing tablet specimens for spectrographic analysis is now available from *Harry W. Dietert Co.*, 9330 Roselawn Ave., Detroit. The press is used to briquette powders, borings, milled chips of metals or other materials into tablets, which are placed in the spark or arc gap of the spectrograph.

The press consists primarily of a hydraulic pressure system and a press containing the tablet mold. A heavy duty hydraulic pump is directly connected to a ¾ hp. motor. Within the base of the machine is a 10-gal. oil reservoir.



Cast iron steel and other hard materials are briquetted with a pressure of 15,000 lbs.; softer materials are pressed at loads as low as 4,000 lbs. Accuracy of analysis is said to be equal to the accuracy obtained with cast pencil specimens.

● A grade of paint sticks for marking hot metal and another grade for cold metal have been available for some time. Now a manufacturer of both types, *Markal Co.*, 6 E. Lake St., Chicago, announces the development of a single grade for *both* hot and cold surfaces.

Free Service Department

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd St., New York.*

WANTED: Recent college graduate with knowledge of electricity or metallurgy or both to do experimental work. Write full particulars of training, age, salary expected, etc., to Box MA-1.

TIMBER!

A sudden warning crack and the high, clear cry of "Timber . . .!" send another giant of the forest on its way. So nature's cycle of growth and change is brought to an end, and another cycle is begun—that of transforming timber into lumber, paper and a host of other valuable materials.

Throughout this entire process, from the first ringing stroke of the logger's axe, Bethlehem alloys play an important role. As axe heads and other logging tools, as tractor engine-parts, as machine parts in sawmill, paper-mill and rayon-mill, Bethlehem Alloys help to bring the products of the forest to the public.

It will pay you to consider the possibility of using Bethlehem Alloys in your own products. In some cases, major production economies can be realized when the correct Bethlehem Alloy is specified as stock. Nearly always, the quality of the finished product can be increased at little extra cost.

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY

METALLURGICAL ENGINEERING

shop notes

Expensive Boring Replaced by Liners Grouted in Place

by Herbert Chase

When a large sand casting must have one or more fairly large cylindrical holes precisely parallel or in some other exact relation, the usual practice is to core the holes as near to size as conditions permit and still allow for subsequent machining. The casting must then be set up in a boring mill or some equivalent tool capable of machining the holes with required accuracy. This necessitates rather expensive equipment as well as the time of at least one competent machinist and sometimes, in addition, considerable work by the tool room in preparing the necessary tools and keeping them in satisfactory condition.

At least one large maker of machine tools has developed an effective alternative with a noteworthy saving in cost. An important feature is that no boring mill is required, although some lathe work is done and, if extreme precision is needed, an internal grinder may be necessary. Cuts, however, can be far lighter with this alternative method than are usually necessary, on large castings, especially if tubing close to the required hole dimensions is available.

The alternative to boring to finished size consists in using a machined tube or sleeve to form a liner for the required hole, the tube being first machined (at least inside) to provide a bore of required accuracy. The casting is provided with cored holes to receive the liner or liners; the holes are cored to a diameter a half inch or more larger in diameter than the *outside* of the liner, after which the liner is "grouted" in place.

To do this, the liner or liners must be held in the correct relative position and this necessitates a jig, which, however, need not be very expensive. Rings or some equivalent must be provided to prevent the grouting material from running to waste around the ends of the liner, but this is a simple and inexpensive precaution.

It is important, however, to use a grouting metal that will not contract when it solidifies—which, in fact, will preferably expand slightly when it becomes solid. Otherwise the grout will be loose in the hole and may permit of enough play to destroy the required accuracy of alignment. In expanding when it solidifies, the grout, of course, anchors the liner securely, especially if the liner be left somewhat rough on its outer diameter.

In addition, the holes should be cored in the casting with sufficient accuracy to avoid any appreciable variation in the thickness of grout. If the grout is much thicker on one side of a liner than on the other, its solidification will force the liner slightly away from the thick side, so that the axis of the liner will not be precisely where intended.

In using this process, this particular machine tool maker employs an alloy containing 50 per cent metallic bismuth, 25 per cent tin and 25 per cent lead. This alloy expands when it freezes—a property imparted by the bismuth. Other alloys containing bismuth in sufficient quantity might also be used, but that mentioned has proved satisfactory. The low melting temperature (about 200 deg. F.) of the grouting alloy is also an advantage; it should be remembered, though, that the method can be used only when the temperature reached by the liner in service is below that at which the grouting alloy becomes soft enough to flow. When the precautions mentioned are observed, the results obtained (in a machine in which the liners used must be parallel and spaced within close limits) are reported entirely satisfactory, and the method is economical.

In this instance, the liners position plain bearings, but the utility of the practice outlined might well be extended to include liners for other purposes. It doubtless could be used also to grout in place solid parts, such as ground shafts that must extend from a casting to form an accurately machined mounting for some other part of a machine.

Blue-black finishes are produced on pins, bushings, etc. by quenching into soluble oil from a molten nitrate salt bath at 700 to 900 deg. F. A fairly permanent gray-black finish, well suited to such products as screws, is obtained by quenching from a draw at 600 to 700 deg. F. into ordinary quenching oil.

—Heat Treating Hints,
Lindberg Engineering Co.

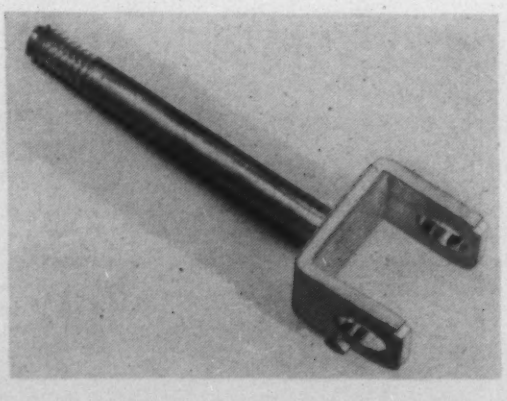
In machining dense, close-grained aluminum bronzes like Ampco metal, tools made of the readily obtainable cobalt steels are best for roughing operations, since they are tougher and retain their cutting edges better than ordinary tool steels. For finishing operations, tungsten carbide tools are preferable, though not essential.

—Engineering Data Sheets,
Ampco Metal, Inc.

Die Casting vs. Assembly of Stamped and Screw Machine Parts

by L. P. Held
Mt. Vernon Die Casting Co.

Designers interested in low-cost products usually aim at a minimum number of parts, the fewest possible machine operations and the simplest and quickest assembly attainable, as well as at low tooling costs. For this reason, one often finds a single die casting taking the place of an assembly built up from stamped and screw machine products.



A very good example of this type of design-choice is the number-stamp part shown here. Originally, the U-shaped part was first stamped and pierced, then formed.

(CONTINUED ON PAGE 62)

Afterward it received two pivot pins and a stem with a threaded end made in a screw machine. Today, this assembly is a single zinc alloy die casting, produced in one piece that includes the U-shaped portion having holes in accurate alignment, a pair of pivot pins cast integrally and a stem that is also an integral part of the casting. Also formed by the die are V-shaped slots, which provide a dovetail for fastening the casting to a mating part.

The only machining required is to ream the holes, as the thread at the end of the stem is cast. An equivalent machining operation was required on the stamped part as well as some others not needed on the die casting, which is held within close dimensional limits. No screw machine operations are needed and the one-piece die casting, of course, reduces assembly costs to zero, as far as this element is concerned.

A single inexpensive die does the whole job, hence tooling cost is less than for the parts formerly used. The zinc alloy die casting is not subject to red rust, as steel parts would be, and is amply strong for the operations required.

For stripping tin coatings from brass or copper, a product known as "Ferrisul" (90 per cent ferric sulphate; manufactured by Monsanto Chemical Co., Merrimac Div., Boston) is said to be satisfactory. For example, a solution of 10 grams of Ferrisul and 10 grams sulphuric acid per 100 cc. removes a 0.0005-in. hot-dipped tin coating from 70/30 brass in 5 min. at 165 deg. F. and in 15 min. at 83 deg. F. Brass is attacked about 1/3 as fast as the tin, the rate of attack being greater on high brass than on low brass or copper.

—*Tin and Its Uses,*
Tin Research Institute

Welding Aircraft Fuselage Tubing

by Hanford Eckman
Piper Aircraft Corp.

A number of useful details of our practice in the oxyacetylene welding of thin-walled tubing in fuselages for light planes may be of interest. These "kinks," together with the basic use of tubular design and oxyacetylene welding, have resulted in a high rate of production with a minimum of special tools and jigs.

Stock tubing is received in 12 to 20-ft. lengths, cut to size and then shaped for assembly. The various jigs used for holding the tubing during the shaping operations are

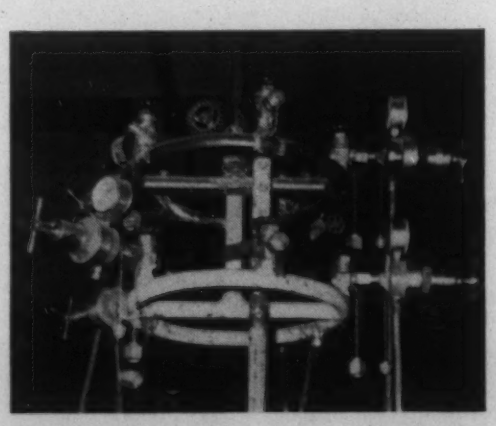


Fig. 1.

Nothing succeeds like success! SHOP NOTES has been promoted from a lowly position near the end of the magazine to one nearer the front. This added prominence should entice even more contributors to submit material for publication here.

Authors in the SHOP NOTES department find themselves in the best of company, too—"names" like Berlien, Chase, Eckman, Held, Isenburger, Longwell, Mudge, Robbins, Schlegel, Wilcox, etc. can and do grace the best pages of the metal magazines. And, in addition, we'll pay contributors for all original items accepted.—The Editors.

fabricated by bronze-welding, a process that is particularly effective for this type of work because of its great flexibility and speed.

The bronze-welding in addition has been considerably speeded by the use of a vapor flux dispenser (made by Linde Air Products Co., 30 E. 42nd St., New York), which causes the acetylene as it flows toward the blowpipe to pass through a liquid flux; the flux is entrained as a vapor and passes through the blowpipe directly to the point of operation—in automatically controlled amount and at just the right moment. Bronze welds so made are sound and of excellent appearance.

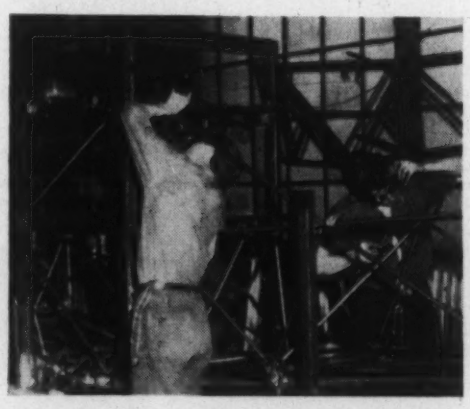


Fig. 2.

The various shaped tubular members are then fabricated into component aircraft parts. Manifolded oxygen and generated acetylene are supplied through a piping system that terminates in a number of strategically located drop rings similar to that shown in Fig. 1. These drops provide for a total of 124 separate welding stations, all so positioned as to provide the maximum effective working space for each operator. In addition, the method of suspension from above conserves valuable unobstructed floor space all along the line.

In the fuselage department the shaped sections of tubing are set up in jigs for tack-welding. The jigs (Fig. 2) are of heavy rigid construction, and provide for exact positioning and firm clamping of the members; if unfavorable warpage is likely, provision is made for keeping the body of the metal cool during welding, yet jig construction is such as to prevent the edges to be joined from becoming unduly chilled.

On completion of tack-welding, the fuselages are mounted fore and aft in wheeled dollies like that in Fig. 3 and passed along to be finish-welded. This last operation is

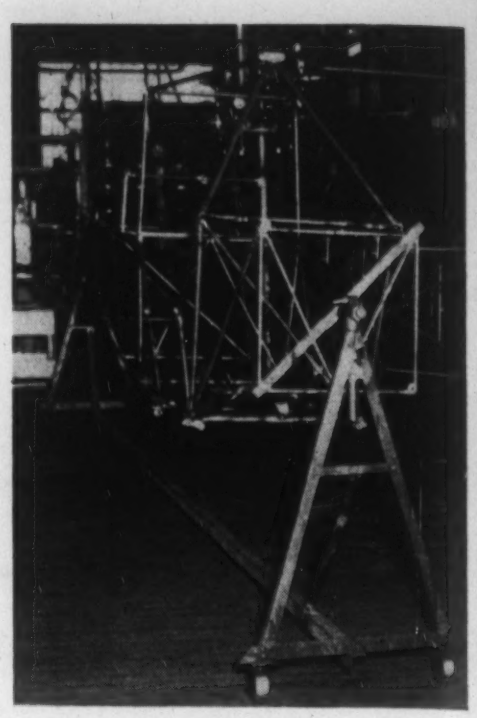


Fig. 3.

facilitated by rotating the entire fuselage in the dolly in order to obtain the best possible welding position for each joint.

—From a paper presented before the *American Welding Society*

Carbide Tools for Steel Cutting

by James R. Longwell
Carboloy Co., Inc.

In selecting the proper standard carbide tool for any job, or designing a special tool where standard tools cannot be used, a few simple considerations are important:

It must be remembered that with carbide tools, part of the steel shank is milled away for the brazing-in of the carbide tip. It is necessary, therefore, to increase the thickness of the shank over that used for high speed steel tools, to compensate for this recess. It is the shank, of course, which resists the downward, sideways and twisting cutting pressures. In selecting a tool, pick one with a shank heavy enough to handle *all* the jobs on which the specific tool is to be used.

In addition to its effect on strength, the size of the shank affects heat dissipation; the larger the size of the shank, the faster the heat dissipation—a desirable characteristic with carbide tools in view of the vastly higher cutting speeds and chip removal of which they are capable.

Tip proportions should be selected so that when the tool is worn out there is a minimum of carbide left. The thickness should be roughly 50 per cent greater for cutting steel than for cutting cast iron. The tip should be thick enough to allow the tool to be ground on top and yet not be too thin before the area has been reduced to a minimum by regrinding.

A little extra thickness is required for machining that involves interrupted or eccentric cuts, unusually deep cuts, and where machines have considerable backlash. As a general rule the tip width of a side cutting tool, for instance, should be half the length, since wear and grinding reduce the tip size in about those proportions, under average conditions.

Metallurgical Engineering Digest

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Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

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4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

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1 Production

OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

Sand Cores at High Temperatures

"Core Behavior at Elevated Temperatures." Harry W. Dietert. *Foundry*, Vol. 68, Oct. 1940, pp. 52, 112, 113. Investigation.

Although foundry engineers are familiar with methods of controlling the physical properties of cores at room temperature, very little definite information on core behavior at molten-metal temperatures is available. In general, it is known that at such temperatures a core first expands, and then collapses when the bond (oil, say) is destroyed by the heat.

Specifically, it would be desirable to be able to control this expansion and collapsibility of cores at high temperatures through tensile strength and core hardness test data. The author has therefore correlated thermal expansion and collapsibility with core hardness and baked tensile strength, using a special dilatometer furnace for both expansion and collapsibility tests. The core specimens were prepared from a mixture of Michigan City lake sand, (A.F.A. fineness 55), 1.3% cereal binder, and linseed-oil-base core compound varied from 2% to 1% by volume; the specimens were baked at 400° F.

As the tensile strength and hardness of a core decrease, its expansion decreases rapidly. A tensile strength of 190 lbs./in.^{2} and hardness of 75 correspond to an expansion of 0.091 in./in. of core length; with the strength at 130 lbs./in.^{2} and hardness at 59, the expansion becomes 0.004 in./in. Thus *cat whiskers, fins, hot cracks* and other defects attributable to high expansion may be held in check by keeping strength and hardness at the lowest feasible levels.

Likewise core collapsibility, and therefore such defects as *dirt* and *core washes* (too-fast collapsing) or *hot cracks* and difficult shakeout (too-slow collapsing) may be controlled through core tensile strength and hardness. Strong cores (190 lbs./in.^{2}) collapse slowly (6.3 min.) whereas weaker cores (130 lbs./in.^{2}) collapse fairly rapidly (4.1 min.)

Core permeability and clay content also influence the rate of collapse. Increasing the clay content serves to retard collapsibility. Also, as core sand becomes finer the core will collapse more slowly and will require more effort to shake out. FPP(1)

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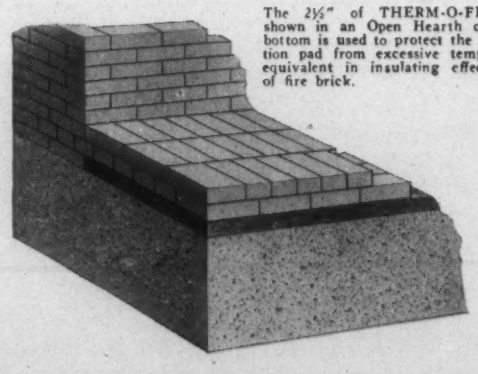

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Bessemer Steelmaking

A Composite

The revival of American interest in the Bessemer process of steelmaking continues, impelled by new methods of controlling the uniformity of the product (see "Jones and Laughlin's Controlled Bessemer," METALS AND ALLOYS, Vol. 10, July 1939, p. MA 454, and "The Acid Bessemer Process of Steelmaking" in the Sept. issue, p. MA 528) and the independence of the process on the availability of steel scrap. Nevertheless the ratio of Bessemer steel production to open-hearth production is still declining slowly.

The Acid Process in America

A searching review of the history of the acid Bessemer process in America, its present status and possible future trends is given by H. W. GRAHAM of Jones & Laughlin Steel Corp. ("The Acid Bessemer Process of 1940," *Metals Tech.*, Vol. 7, Oct. 1940, 17 pp.) The downward trend of the ratio of Bessemer production to open-hearth will continue for the next few years, only new applications for Bessemer steel in place of open hearth, or a large market for entirely new Bessemer products, being capable of changing the trend.

On the other hand economic trends, particularly the decreasing availability of steel scrap, of the next decade or two will favor a revival of converter operation for Bessemer ingots or duplex metal. The revival will be limited only by the rapidity and completeness with which management, operators and metallurgical engineers solve the manufacturing and quality problems involved.

Bessemer steel uniformity has always been limited by difficult metallurgical control and by the small size of individual heats. The above-mentioned recently developed control method, however, is said to offer possibilities of controlling the Bessemer process with a precision impossible in open-hearth steelmaking. Essentially, the Bessemer process involves only one raw material (liquid pig iron), to which only one processing material (compressed air) is added. Two blows of Bessemer steel will thus be alike if blown from iron of the same analysis and "turned down" at precisely the same point.

However, variations in the heat-producing constituents of the iron are usually compensated for by variation in the cooling materials used—scrap, ore or steam. The silicon content of the pig iron is a very important and often insufficiently controlled variable; it seems that if the highly desirable close control of silicon content is to be achieved, the blast furnace must be operated at a lower silicon level, with ferrosilicon added to the analyzed iron to bring the silicon content of the Bessemer charge *up* to some uniform level.

Other developments that are practically essential to enhanced utility of the Bessemer process are (1) a dependable device for measuring iron temperatures (photocell equipment, already developed), (2) refrigeration of the Bessemer blast to uniform temperature and humidity, (3) better control of blast pressure and volume.

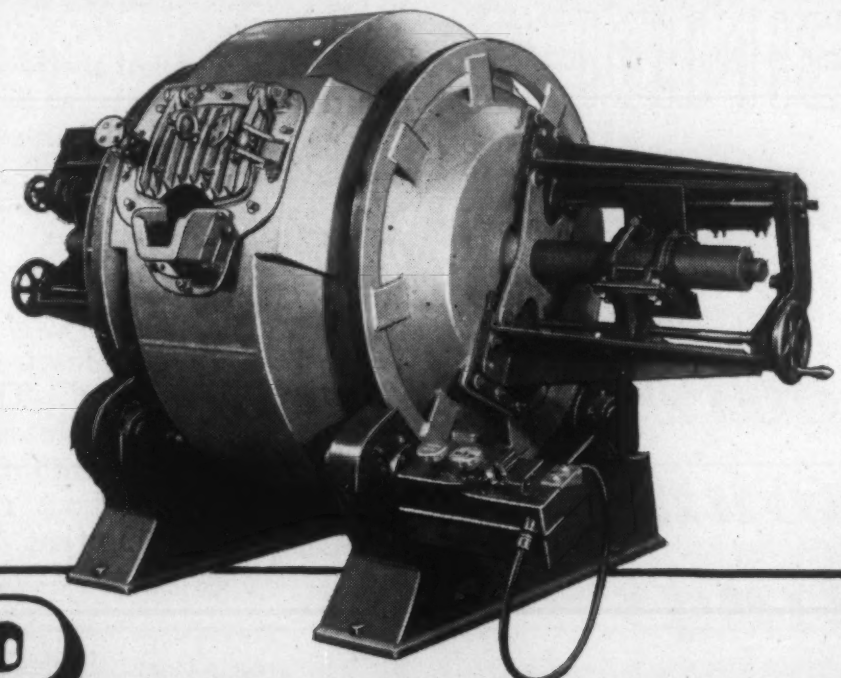
The "modernizing" of Bessemer steels' physical properties depends on considerations of hardness, embrittlement and aging. Tensile tests of specimens of various nitrogen contents show that the normal tensile strength increases with increasing nitrogen; thermal aging raises the ultimate strength, and this effect increases sharply with increasing nitrogen. Work hardening, cold-work-embrittlement, time-aging, etc. may also be similarly affected by nitrogen content.

Dephosphorizing Acid Steel

A recent development in American practice, intended to produce a low-phosphorus Bessemer steel (for uses to which the normal grade is not adapted) from the generally available ores, is described by G. M. YOCOM of Wheeling Steel Corp. ("A Method of Rapid Dephosphorization of Bessemer Steel," *Paper, Am. Inst. Mining Met. Engrs.*, Oct. 1940, 15 mimeographed pp.). The new practice involves dephosphorization by treating the blown steel with a basic material during transfer to the ladle, and is of interest not only from the processing viewpoint, but because it appears to provide a steel with inherently different properties than those of normal acid Bessemer steel and soft open hearth steel.

The highly siliceous converter slag must be separated from the blown metal before dephosphorizing with basic materials, so the converter practice is controlled to produce a thick viscous slag that can be mechanically held back from the pouring lip when the vessel is tilted. Young blowing, and higher ratios of silicon to manganese (2½ to 1) in the iron, produced the best type of slag.

Blown metal temperature must be higher than normal in order to melt the dephosphorizer, added in the cold state. The control of manganese and silicon just mentioned is effected not by selecting ores,



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but by adjusting the silicon content of normal irons. The (dry) dephosphorizing material—a mixture of 50% impure lime, 30% roll scale and 20% flux, made up shortly before using—is added to the stream of metal as it is being poured from the converter into the steel ladle.

The degree of phosphorus elimination is proportional to the amount of dephosphorizer used, beyond that required to neutralize acid contamination. Blown metal phosphorus contents of 0.09-0.10% are reduced to 0.035% P by treatment with 78 lbs. of dephosphorizer/ton; to 0.050% P with 62 lbs./ton; and to 0.065% P by 54 lbs./ton.

The hot working and rolling quality of the dephosphorized steel is superior to the untreated normal-phosphorus product. The lowest-phosphorus Bessemer steel closely approaches the mechanical properties of soft open hearth steel. In certain products the low-phosphorus steel is better than either open hearth or regular Bessemer steel. The extra cost of the method is low, and the cost differential between open hearth and Bessemer steel is not destroyed.

Among the disadvantages of the method are: (1) Lower yields are obtained owing to the use of iron of higher metalloid content. (2) Only 3% of scrap is melted, as against 7-8% for normal practice. (3) The method is limited to the production of soft steels.

Adapting the Acid Process Abroad

American iron is low in phosphorus, and, of course, the acid process is almost exclusively used. Abroad, however, so much high-phosphorus iron must be employed that the basic Bessemer process is in wide use. However the cleaner steel characteristic of acid practice can be produced by after-treatment of acid Bessemer steel with dephosphorizing slags, either by the Perrin process or by duplexing acid steel in basic electric furnaces.

The Perrin process for de-phosphorizing (in the ladle) the acid Bessemer product so as to permit the production of low-carbon steel ingots from high-phosphorus iron in acid converters, is examined by B. YANESKE ("The Manufacture of Steel by the Perrin Process," *Iron & Steel Inst.*, Adv. Copy, Sept. 1940, 38 pp.) After considerable investigation, a plant using the Perrin process is to be constructed in India.

In the process molten steel is poured into molten slag, and depending on the slag composition, the steel is either deoxidized or dephosphorized. At Tata it has been found practical to blow hot metal containing about 0.30% P in an acid converter and to remove most of the phosphorus in the blown metal by pouring it into a basic oxidizing slag in the casting ladle. Alloys are then added in a red-hot condition to the steel and it is poured into ingots. The slag may be either a synthetic slag (preferable) or a basic open-hearth slag low in acids and high in FeO.

Attempts to improve the quality of rimming Bessemer steel to make it more competitive with open hearth are reported by R. LEMOINE ("Note sur un Procédé d'Amélioration des Aciers Thomas Doux Effervescents," *Rev. Met.*, Vol. 36, Dec. 1939, pp. 522-524). Duplex treatment of the Bessemer steel in a basic electric furnace with 2 slags (an oxidizing dephosphorizing slag and a reducing finishing slag) lowered the phosphorus, but rimming action was irregular, quality was improved only slightly, and the 2 hrs.' time in the electric furnace increased the cost too much.

A successful practice finally developed comprised subjecting the Bessemer steel to an alkaline treatment (sodium carbonate or derivatives) in the ladle en route to the final electric furnace refinement, which lasted 40-50 min. The phosphorus was markedly decreased, the sulphur somewhat lowered, and rimming action was uniform. Extra cost was not excessive and the elongation of the finished steel exceeded that of open hearth steel of equivalent analysis.

X (1a)

Cast Iron Ingot Molds

STUDY OF THE IMPROVEMENT OF CAST IRON INGOT MOLDS ("Untersuchung zur Verbesserung der Kokillenhaltbarkeit") A. RISTOW. *Stahl u. Eisen*, Vol. 60, May 9, 1940, pp. 401-404, 427-433. Research.

Records were kept of ingot mold life, expressed in kg. of mold used per ton of steel cast, for various gray cast iron mold compositions.

Raising the manganese content of the cast iron decreased mold life, whereas raising the silicon content increased it. For relatively small molds graphite content of 2.8 to 3.2% gave the best life. The combined-carbon content should be on the low side. More conical and longer molds, with a ratio of mold weight to ingot weight of 1:1 or 1:1.3 gave the best results.

The longest mold life was obtained when the ingots were stripped as soon as possible after pouring, say within about 1½ hrs. Quenching the hot molds in water or spraying them was detrimental. It is best to cool the molds slowly. They should not be used more than 2 or 3 times a day.

SE (1a)

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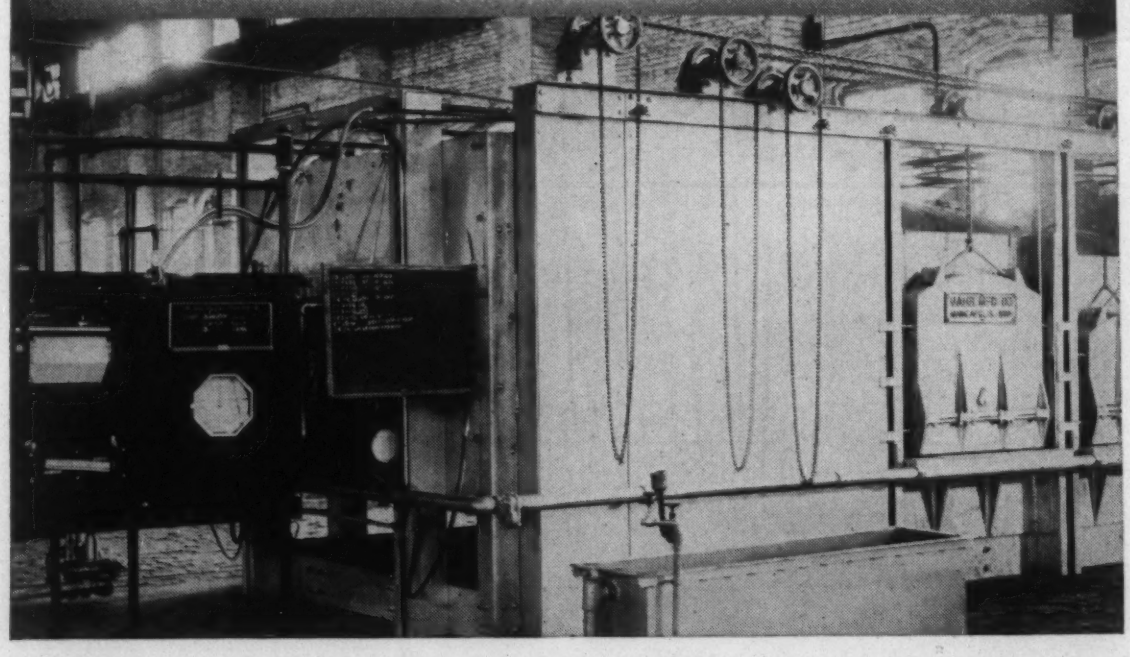

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Annealing Deep-Drawing Steel

A Composite

Comprehensive German investigation of the process of annealing cold-rolled strip steel to be deep-drawn into "small hardware and fittings" will interest American metallurgical engineers studying the same problem. [*German publications, after several months of extremely irregular and delayed delivery, are now reaching this country with reasonable promptness by way of Siberia and Japan.—Ed.*] Attention is paid to the merits of continuous annealing (normalizing) as against box annealing, to optimum time and temperature, and to properties obtained—all topics of current metallurgical discussion in this country.

In the first of 2 related studies, A. POMP & G. NIEBCH ("Ueber den zeitlichen Verlauf der Entfestigung beim Glühen von kaltgewalztem Tiefziehbandstahl," *Mitt. Kaiser-Wilhelm-Inst. Eisenforsch. Düsseldorf*, Vol. 22, No. 8, 1940, pp. 109-119) determine the time required for continuous annealing and for box annealing at various temperatures to produce soft material and an annealed structure, the purpose being to explore the possibilities of replacing the generally used box-annealing practice with continuous electric furnace annealing.

Steel strips 8 in. long, 1.6 in. wide and 0.04 in. thick were cold-rolled with 10, 20, 40 and 60% reduction and annealed in a continuous electric furnace for 1-3 min. at 1200°-1650° F.; tensile properties and structure were compared with those of conventionally box-annealed strip.

Samples rolled with 40 and 60% reduction were fully softened at 1200° F. after 1.5 min., and at 1470°, 1560° and 1650° F. after 1 min.; longer annealing times at these temperatures brought no further change in mechanical properties. Tensile strength and elastic limit were up to 7% higher in the continuously heated than in the batch-heated samples. The ratio of elastic to ultimate strength was about the same, while the elongation at fracture was slightly higher than in the batch-heated sample.

After the shorter times of annealing at the higher temperatures, the structures were the same for both types of heating, but if the time of annealing was extended the continuously annealed samples showed distinct cementite formation, owing to recrystallization, which does not occur in ordinary box-annealing.

The samples cold-rolled with 20% reduction were fully softened at 1200° F. after 3 min. continuous annealing, at 1300° F. after 2.5, at 1380° F. and 1470° F. after 1.5 min., and at 1560° F. and 1650° F. after 1 min.; no further change took place with longer annealing times. Tensile strengths practically equivalent to those of the batch-annealed samples were obtained at all annealing temperatures under A_3; the elastic limit and the ratio of elastic to ultimate strength were, however, considerably lower for the continuous annealing, and the grain was slightly coarser.

Cold-rolled samples with 10% reduction were fully softened only at furnace temperatures of 1470° F. and higher—after 2 min. at 1470° F., 1.5 min. at 1560° F., and 1 min. at 1650° F. The mechanical properties were about the same as those of the 20% reduced and continuously annealed samples, but the grain was distinctly coarser even before complete softening.

Thus, low-carbon steel loses the hardening due to cold-rolling after short annealing times; for temperatures under A_3, the strip rolled with higher reduction will become softer in shorter time; for temperatures over A_3, the time is not necessarily shorter because of high reductions. The continuous electric annealing process promises successful application for cold-rolled deep-drawing steel.

In the second part of this research, POMP & NIEBCH ("Das Blankglühen von kaltgewalztem Tiefziehbandstahl im Durchziehofen," *Ibid.*, pp. 121-136) make extensive comparison of the mechanical properties of two 0.06% C strip steels annealed by the two methods. The analyses of the 2 steels were similar except that steel 1 had 0.009% P and steel 2 had 0.023% P; steel 1 showed 0.07% Cu, and steel 2 contained 0.16% Cu. Both steels had Ac3 points at 1615° F.; steel 1's Ac1 was 1346° F. and steel 2's 1337° F. Steel 1 was "probably" made in the electric furnace, and steel 2 (killed with aluminum) in the open hearth.

Strip-speeds of 25 in./min. to 10 ft./min. at 1100°-1800° F. were studied. No significant property variations were recorded below 1200° F., these temperatures being too low for useful softening. At 1300° F. strip velocity within the range studied had no noticeable effect on the results obtained. Steel 1, no matter what its prior cold-reduction, developed about the same properties as the box-annealed material and was slightly superior in elongation at fracture deep-drawability and elastic ratio.

With steel 2, however, continuous annealing at 1300° F. gave results inferior to batch annealing. On the other hand, at

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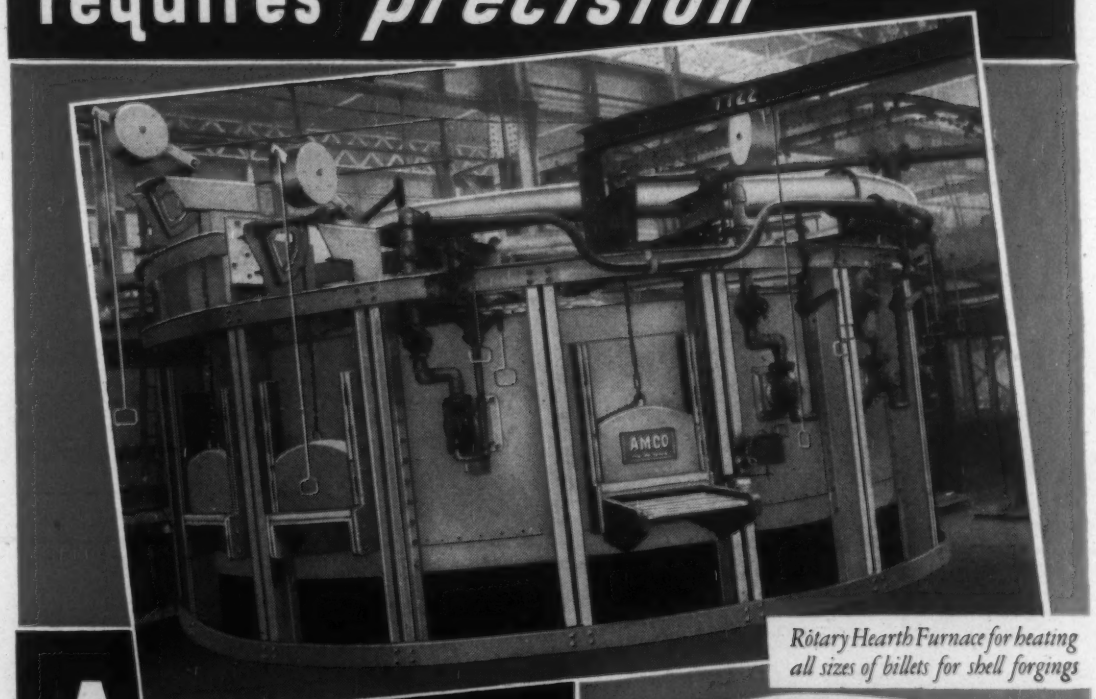

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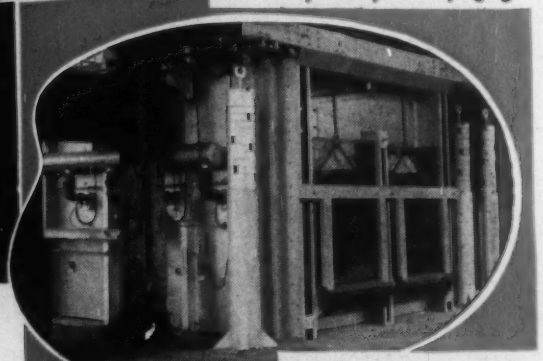
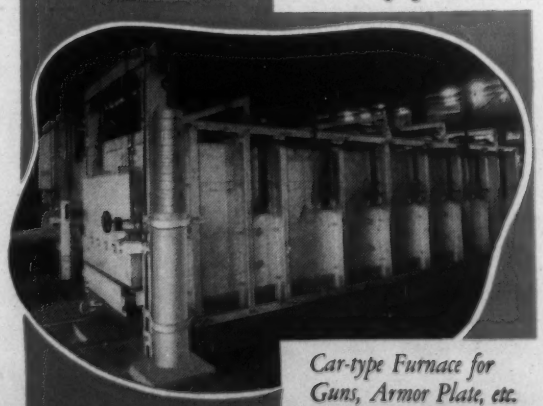


Gun Forging Furnace



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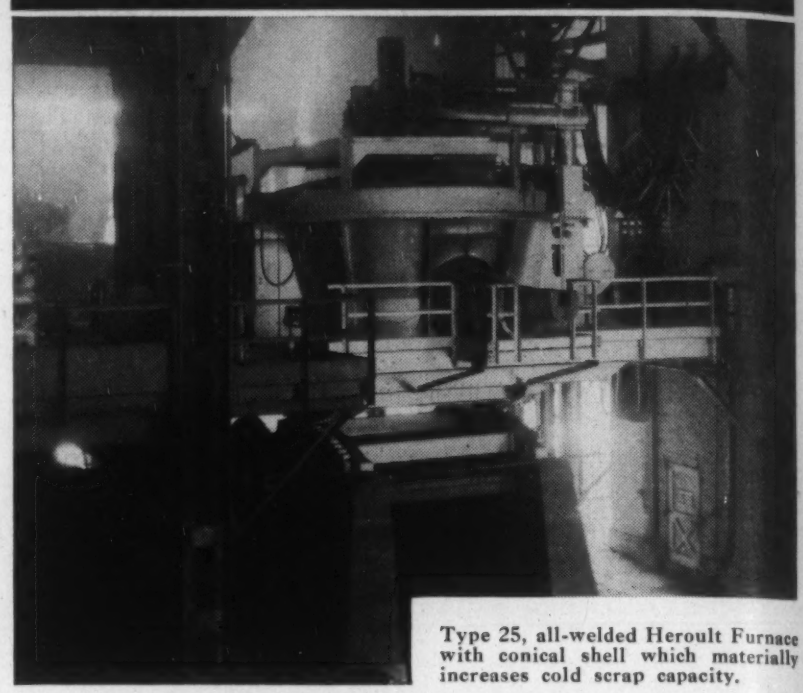

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higher temperatures continuously annealed steel 2 developed a higher tensile strength and elastic limit than, and about the same elongation and deep-drawability as, the batch-treated samples. The difference in behavior of the 2 steels is ascribed to differences in their manufacturing (melting) methods. Ha (1a)

Applied Tension in Cold Rolling

EFFECT OF FORWARD AND BACKWARD PULL IN THE COLD-ROLLING OF STRIP STEEL IN A 12-ROLL COLD-ROLLING STAND ("Einfluss des Haspel- und Bremszuges beim Kaltwalzen von Bandstahl auf einem Zwölfwalzen-Kaltwalzgerüst") W. LUEG & F. SCHULTZE. *Mitt. Kaiser-Wilhelm-Inst. Eisenforsch., Düsseldorf,* Vol. 22, No. 7, 1940, pp. 93-108. Research.

This is said to be the first attempt to determine the effect on rolling pressure of backward or forward tension (or both together) exerted on the strip in cold-rolling. The experiments were made on a cluster-roll stand with working rolls of 3/8 in. diam. and 3 1/8 in. length, 2 intermediary 3/4-in. supporting rolls and 3 outer 1.5-in. supporting rolls of 40 mm. diam.; deep-drawing steel strip 0.6 in. x .020 in. was rolled.

The conclusions drawn are that rolling pressure and average deformation resistance decrease a little more than linearly for all reductions with increasing forward tension (pull); for a tension of 35,500 lbs./in.^{2} the pressure at a 10% reduction was 31%, and for 50% reduction about 10%. When the rolls were lubricated, these two figures became 33 and 13%, respectively— practically the same as when unlubricated. The "advance" increased considerably with increasing forward pull, *e.g.* for 49,800 lbs./in.^{2} tension and 30% reduction an increase from 2% to 23% without, and from 2.5% to 31% with lubrication.

All these figures were obtained with soft-annealed strip; practically the same results were found with previously-rolled strip (without lubrication). When rolling previously-rolled strip, with simultaneous application of forward *and* back pull, the influence of the back pull on decrease of rolling pressure and deformation resistance was smallest at small reductions and gradually increased with increasing reductions; this is just opposite to the effect of the forward pull.

The effect of the back tension is almost independent of the simultaneously present forward tension. Compared with the forward pull, the effect of the back pull was greater, particularly with greater reductions. For 40% reduction and 28,400 lbs./in.^{2} pull in both directions, the reduction of the rolling pressure by the back pull was about 3 times as much as that by the forward pull. The "advance" decreased with increasing back pull. Ha (1a)

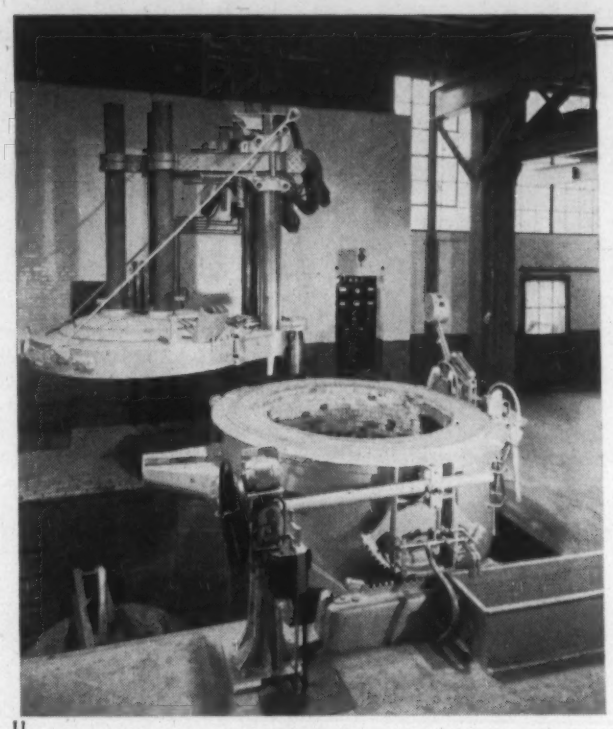
1b. Non-Ferrous

Copper Refinery Slags

A Composite

Some recent Russian work on the handling of slags during copper refinery operations and the disposition of slags after run-off should be of interest to American metallurgical engineers in the copper-producing industry.

Working with smelter slags of 55% SiO_2, 20% FeO, 8% CaO and 20% Al_2O_3, D. M. YUKHTANOV ("The Influence of Sodium Oxide on the Properties of Slags of Karsakpai Copper Smelter," *Tsvetnye Metally,* No. 10-11, 1939, pp. 108-122;



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in Russian) attempted to lower their melting temperatures and viscosity.

Introduction of alkali into the charge lowers considerably the melting temperature of the slag. Addition of 2% Na_2O lowers the melting temperature by about 200° F. The viscosity of the smelter slags, 420 poises at 2340° F., is lowered to 120 poises by the introduction of 2% Na_2O. The lowering of melting temperatures and the increase of fluidity result in economy of fuel and in the decreased losses of copper in the slags.

Other methods of decreasing the losses of copper in the slag are reported by V. S. SOKOLOV ("Refining of Converter Copper," *Ibid.*, No. 2, 1940, pp. 46-54; in Russian), based on experiments in a 110-ton furnace. Decreasing the time of blowing, and some changes in the working of the heat, reduced the copper losses in the slag from 13% to 5%. The amount of nickel and antimony in the copper, however was not reduced.

The possible use of copper refinery slags for neutralizing electrolytes is explored by A. I. LEVIN ("The Use of Refinery Slags for Neutralization of Electrolytes at Kyshtym Electrolytic Copper Works," *Ibid.*, No. 9, 1939, pp. 85-94; in Russian). With the use of special "aerolift" apparatus designed by the author 98% of the free sulphuric acid of the electrolyte can be converted into copper sulphate.

For best results it is necessary to observe the following conditions: electrolyte should be diluted to sp. gr. of 1.14 to 1.16; the temperature of the initial electrolyte should be maintained at about 175° F.; the ratio of weight of slag to weight of free sulphuric acid should be 5 for slags crushed to 8-12 mm. size, 4.8-5.2 for 5.8 mm. size, 4.5-4.8 for 5 mm. size, and 4 for more finely ground slags. Certain impurities such as clay hinder the process and should be removed from the slag. Agitation is necessary.

The commercial use of this practice for producing copper sulphate from refinery electrolytes by treating with slag is described by B. A. RYABKOV ("The Use of Refinery Slags for Neutralization of Electrolytes in the Production of Copper Sulphate at Kyshtym Electrolytic Copper Works," *Ibid.*, No. 10-11, 1939, pp. 102-106; in Russian). The iron from slags is precipitated out in evaporators and extracted with other anhydrous salts of copper, nickel and arsenic. The copper sulphate after the second crystallization contains 21-24.6% Cu, 0.5-0.8% Ni, up to 0.39% Fe, and 0.2-0.38% free H_2SO_4. This product is further refined by recrystallization. BND (1b)

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Aluminum Alloy Castings

"POROSITY IN ALUMINIUM-ALLOY CASTINGS." *Foundry Trade J.*, Vol. 63, Oct. 3, 1940, pp. 217-218; Oct. 10, 1940, pp. 243-244. Abridged from *Aluminium Technique.*

The characteristics peculiar to light alloys, indices of porosity trouble, influence of alloy composition, melting practice, temperature and time factors in melting, removal of gases from the melt, porosity in pressure die-castings, sand molds, design of permanent molds, dies for pressure die-casting, etc. are discussed.

The greater part of the porosity encountered in defective castings is due to gas—principally to hydrogen absorbed as such, and to hydrogen generated from steam decomposed by molten aluminum. On these grounds reverberatory furnaces cannot be recommended for the melting of aluminum for casting purposes. Where pot furnaces are used, the design should be such that combustion gases cannot reach the surface of the melt by passing above the rim of the crucible.

Irrespective of the melting system employed, 3 factors must be borne in mind when melting metal for sand and permanent mold castings. First, the charge should be run down at a reasonably rapid rate to avoid, in the heated (but solid) state, undue exposure and possible contamination. Second, it should be heated only to that temperature above its melting point which experience has shown to be essential to attain ideal pouring conditions for the prevailing section of the casting, or for the particular size of casting under production. Finally, with the melt up to required temperature, it should not be allowed to "stew" for any longer period than necessary.

An average pouring temperature for all aluminum alloys may be taken to be about 1300° F. An upper limit of 1435° F. has been quoted for thin-walled castings to be produced in certain of the more difficult alloys, while 1250° F. has long been given as the lowest permissible figure, this being applicable to castings of the largest size. Eutectic silicon alloys, which are "modified" with sodium or sodium salts, must be heated to about 1375° F. before pouring.

The degassing of virgin aluminum alloy melts by the use of chlorine, or certain volatile inorganic halogen salts, finds little application in normal foundry work; this practice is adopted, as a rule, only for such special cases as the production of certain types of cast rolling slabs or extrusion billets. AIK (1b)

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Working of Metals

A Composite

When metals and alloys are cold worked below their recrystallization temperatures they become progressively harder and stronger. Repetition of this extremely elementary fact may seem to many a sheer waste of space, yet sometimes it seems as though it represents the total generalizable knowledge about metal-deformation of which metallurgical engineers can be certain.

How much harder, how much stronger? How shall we evaluate the directional components? What are the effects of prior structure, of purity, of various alloying agents? At what annealing temperatures are these effects obliterated in individual cases? How does working affect other physical properties? When will we be able to measure these effects in a standardized, commonly-accepted fashion? The answers to these questions are of much more than academic importance, for the effects of cold- and hot-work on metals complicate their production and fabrication, and have a determining influence on their final properties and service performance.

Hot- and Cold-Rolling of Steel

There has been no lack of seekers after these answers, and several papers presented at the recent (Oct. 1940) annual meeting of the Am. Soc. for Metals gave new information. N. P. Goss of Cold Metal Process Co. discussed "Structural Changes in Low-Carbon Steels Produced by Hot and Cold Rolling" (*Preprint, Am. Soc. Metals,* Oct. 1940, 14 pp.), giving particular attention to directional properties and describing a simple diffraction method to bring out orientation textures.

An 0.105% C open-hearth steel was hot-rolled, the finishing being carried out below A_3 to develop a strong fiber structure. The objects of the study were to determine (a) the crystallographic directions that lie in the direction of rolling, in the transverse rolling direction and in a direction normal to the surface after drastic hot-rolling below A_3 but above A_1, (b) the effect of subsequent cold-rolling on this hot-rolled texture, (c) the possible differences in the fiber structure, and (d) the effect of heat treatment above and below A_3 on the directional properties of the cold-rolled strip.

It was found that different orientations are developed in the hot-rolled and cold-rolled strip steels and that cold-rolling reorientates the fiber structure of the hot-rolled strip. The differences between the hot- and cold-rolled textures are not disclosed by the Laue method, which is inadequate in dealing with complex orientation structures, but are disclosed by the method employed in this study.

Normalizing at 1700° F. did not remove the directional properties entirely. A weak fiber structure remains even though the grains have recrystallized. Annealing at 1300° F. is less effective in removing the directional properties; in this case, the preferred orientation of the grains is much more pronounced and the grains appear to be small.

An attempt was made by G. L. Clark & W. M. Shafer of Univ. of Illinois ("Quantitative Evaluation of Distortion in Silicon Steel and in Aluminum," *Ibid.*, 23 pp.) to correlate measured stresses with observed effects on X-ray patterns. Strips of 3% Si steel made up of a single crystal were bent in such a way that the radius of curvature could be accurately measured by a modified spherometer, and correlated with the measured elongation of the Laue spots. Under these conditions, radial asterism was observed within the elastic limit and beyond the elastic limit; a part of the rotation or bending of the planes was elastic.

With single crystals of aluminum and polycrystalline aluminum specimens, equivalent amounts of cold-working, whether by rolling or elongation by tension within the limits of deformation used by the authors, produced a similar effect. In bending, the planes tend to rotate or bend about the axis of bending, in rolling to rotate or bend about an axis in the plane of rolling and perpendicular to the direction of rolling,

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and in elongation by tension to rotate or bend about an axis perpendicular to the direction of elongation. Nadai's "octahedral shear" used for expressing the amount of cold-work may be correlated with X-ray patterns of the cold-worked metal for the specimens and conditions applied by the investigators.

Strain Hardening

An outstanding example of the service-utilization of the work-hardening property of metals is the frequent use of the austenitic high-manganese steels (Hadfield steels) by the railroads and industry generally wherever service involves continual cold-working in many small doses, for such steels work harden very rapidly and thus provide a sort of compensating resistance.

The strain hardening properties of such a steel (12.5% Mn, 1.10% C, 0.35% Si) were carefully determined by D. NICONOFF of Republic Steel Corp. ("Quantitative Measurement of Strain Hardness in Austenitic Manganese Steel," *Ibid.*, 19 pp.), who subjected specimens to impacts of different intensities and measured the surface hardness as well as the depth of penetration.

Using cylindrical specimens, it was found that the hardness below the surface first decreases slightly and then increases, reaching a maximum value which appreciably exceeds the surface hardness. Using conical specimens, the hardness of the cold-worked surface was found to be near its ultimate value irrespective of the intensity of the impact. In the lower part of the sample, the hardness effects gradually decline from this maximum value, until the hardness of the original, unstressed metal is reached.

Under repeated impacts, a point was invariably reached where the resulting strain hardness immediately below the surface not only ceased to increase on further hammering, but actually decreased slightly. A greater number of light impacts was required to bring about this point of hardness satiation, rather than the use of more intense impacts. Once the outer layers of manganese-steel are fully hardened, the strain hardening effect has a greater tendency to penetrate within the metal.

Unexpectedly high values were found to be necessary to strain harden flat surfaces to the maximum possible value, with reference to a single impact. To attain under these conditions a Rockwell C hardness of 50, the unit stress concentration necessary was found to be as high as 35,000 ft.-lbs./in.^{2}

Recovery from Cold-Work

The problems associated with removal of the effects of cold-work, are important in the process annealing of metals. ERICH FETZ ("Recovery of Nickel from Cold-Working on Annealing," *Ibid.*, 31 pp.) continues his studies on the factors affecting the recovery of nickel from cold work. In this instalment data are presented on the hardness recovery of mildly deformed nickel at different depths below the surface, and on the effect of thermal pretreatment and grain size on the softening of 3 different kinds of cold-rolled nickel.

For studying depth effects (a) electrolytic nickel annealed in the as-deposited state at 650°F., and (b) electrolytic nickel, twice cold-rolled and recrystallized at 1000°C. were cold-rolled 10% and 25% and part of the surface removed by milling. The work hardening in rolling and its recovery on annealing were tested at the surface, on an intermediate plane and in the central regions. An uneven stress distribution and release of work hardness was found at the surface and inside of the metals. These differences were greater with the coarse-grain material (b) than with the fine-grain material (a).

Only in one case, *i.e.* with the fine-grain material (a) cold-rolled 25%, were identical softening curves obtained throughout the sample. For small plastic deformations, the hardness testing method should not be used, as results vary according to the depth of the penetrator.

A profound effect of thermal pretreatment prior to plastic deformation on both the extension and location of the recovery temperature range was found with carbonyl powder nickel, as-deposited electrolytic nickel and cold-worked and recrystallized electrolytic nickel. Material of the same composition, cold-rolled to the same extent and annealed at the same temperature for the same length of time, was found to lose its work hardness at different annealing temperatures depending on the thermal pretreatment (500° vs. 900° vs. 1300°C.) prior to the plastic deformation.

These differences in the recovery characteristics are attributed to differences in grain size and residual grains prior to cold working. The effect of thermal pretreatment on hardness recovery is least pronounced at severe plastic deformations and greatest at small ones. A characterization of the internal state (microstructure, strains, etc.) of material submitted to recovery tests appears to be mandatory.

EF (2)

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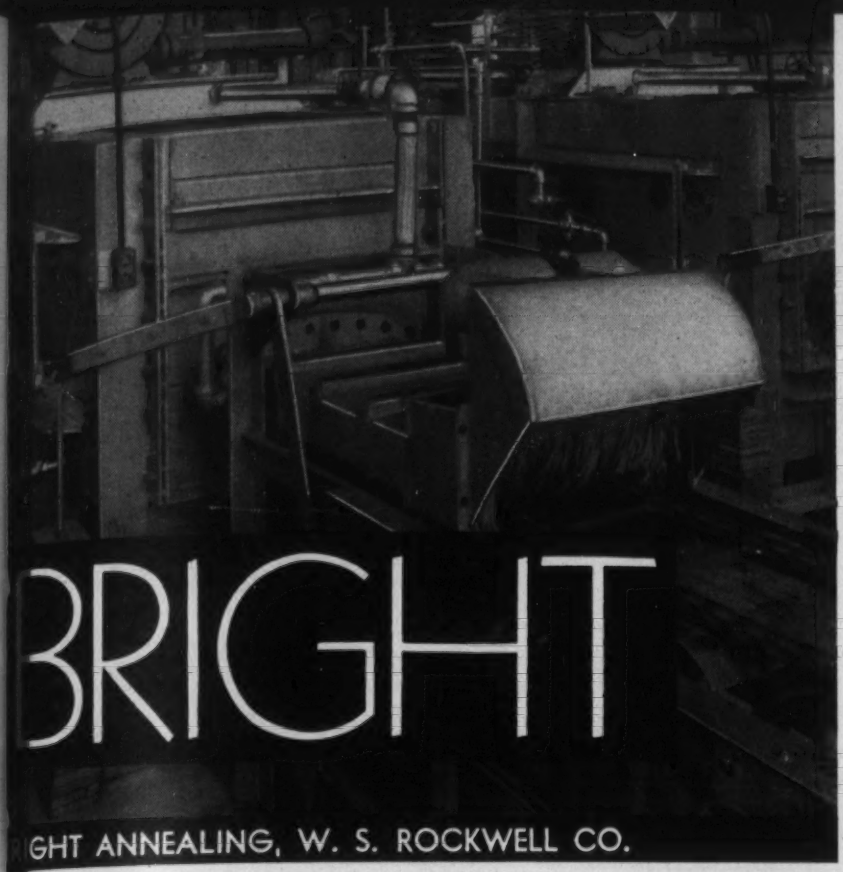

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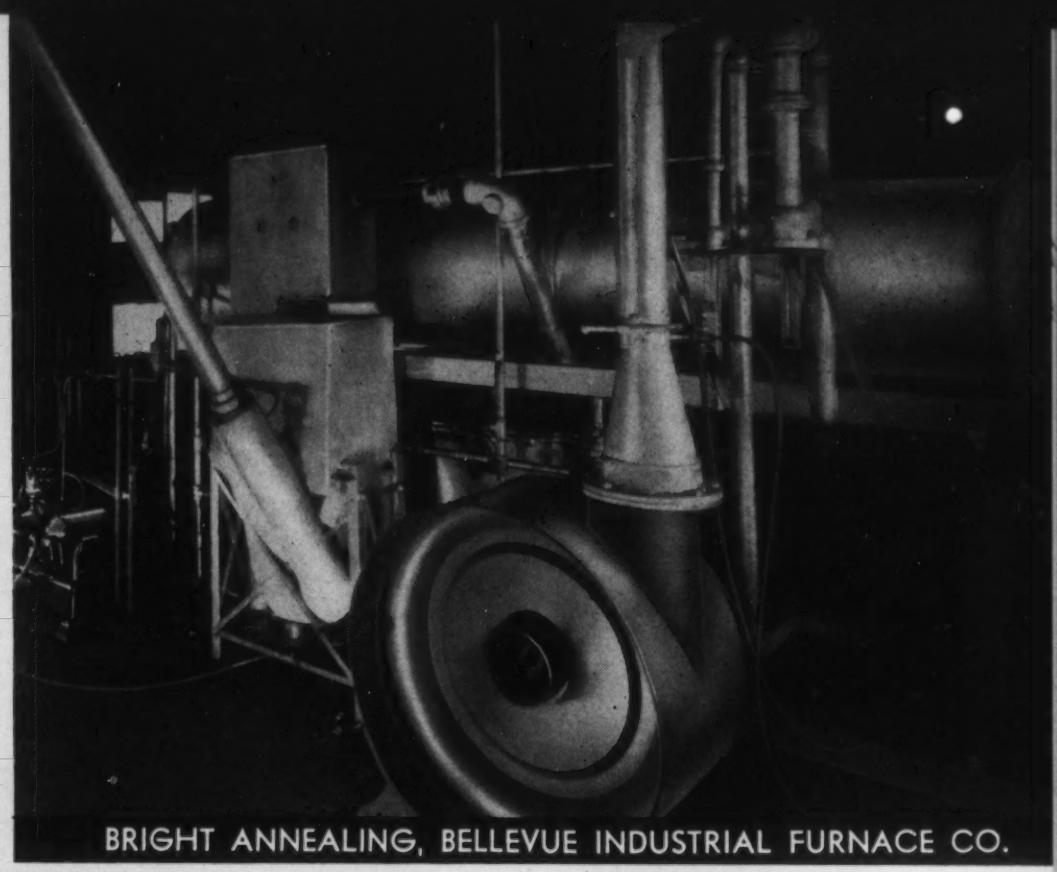

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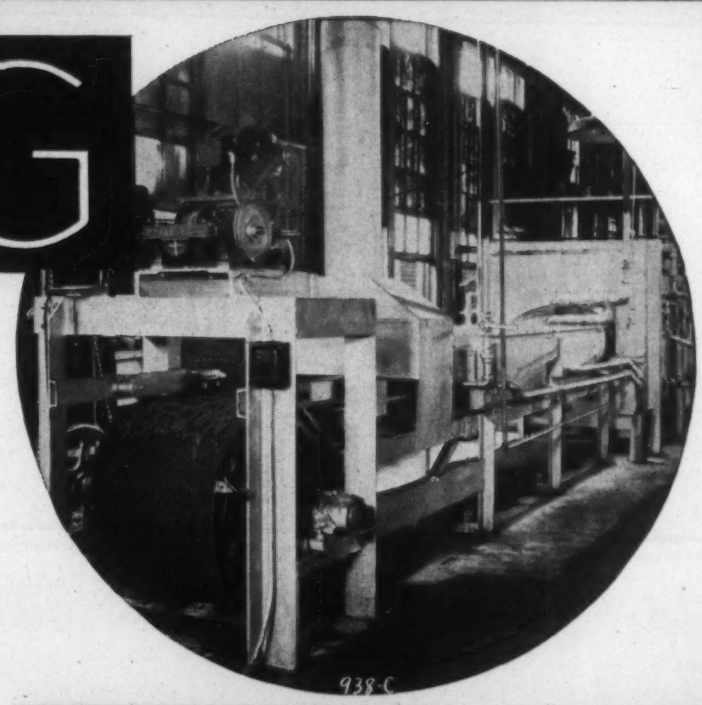

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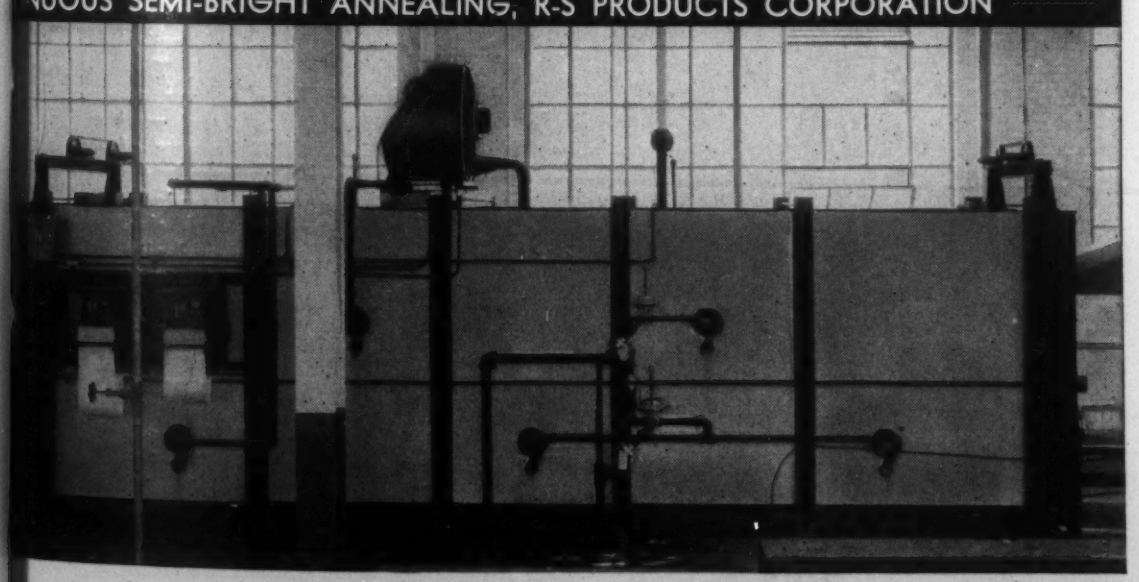

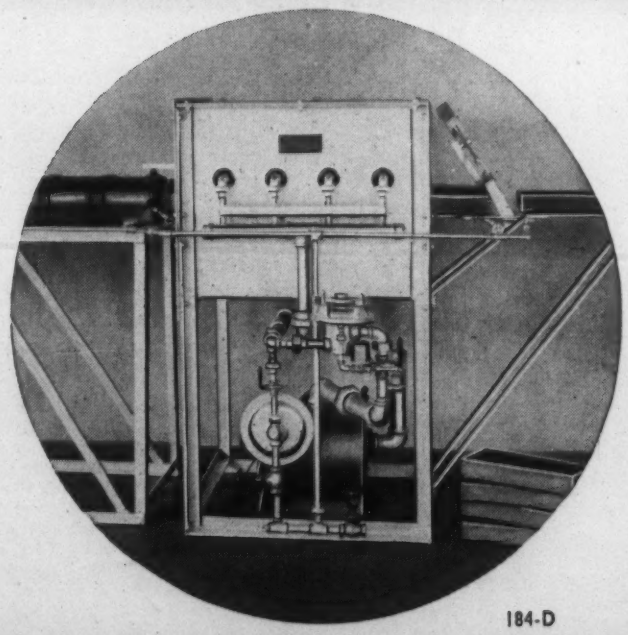

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Salt Bath Pot-Corrosion

"Corrosion of Steels by Molten Nitrates." P. Lloyd & E. A. C. Chamberlain. *Iron & Steel Inst.*, Adv. Copy, Oct. 1940, 15 pp. Research.

The corrosion of steel containers holding molten nitrates used particularly for heating aluminum alloys for heat treating was studied. The process was investigated on a laboratory scale with special reference to the effects of temperature, method of heat application and impurity in the salt, as well as the influence of the material forming the pot.

It was found that, although the corrosion rate increased rapidly with temperature, local overheating of the pot did not necessarily lead to accelerated corrosion at that point. Alkali chlorides, found in most commercial salts, stimulated corrosion. Ingot iron was more resistant to corrosion of the nitrates than steels. JLG (2)

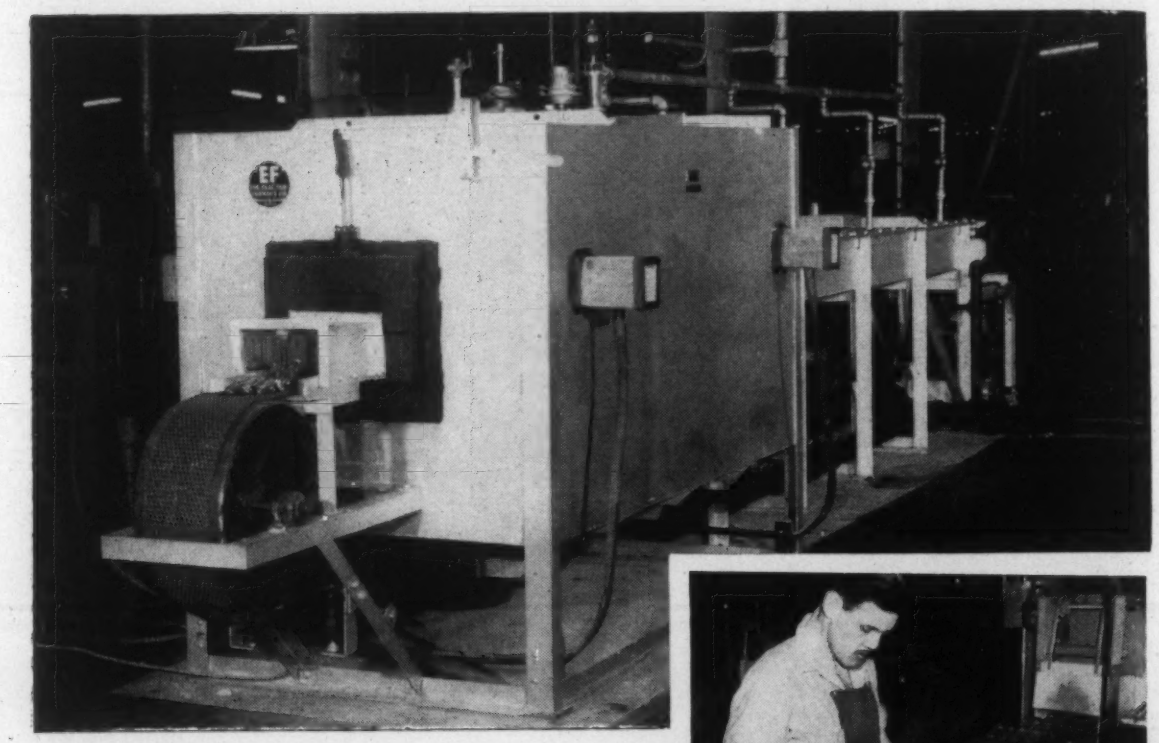
Pre-Plate Polishing

"The Relative Effect of Various Polishing Finishes on Corrosion Resistance of Electroplated Nickel Deposits on Steel." Toledo Branch of the A. E. S. *Proc. Am. Electroplaters' Soc.*, 1940, pp. 144-145. Investigation.

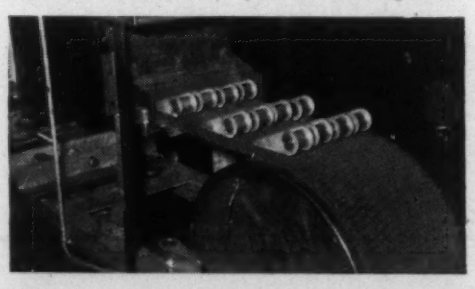
Cold rolled steel was polished with abrasives ranging from 100 to 240 grains, and then plated with a coating of nickel about 0.001 in. thick. The quality of the coating was determined by the salt spray test.

The best results were obtained with steel that had not been subjected to polishing, but which had been buffed with a stitched wheel. The next best results were obtained with steel polished with the finest grain—No. 240. In general, polishing procedures that broke through the cold-rolled skin of the steel increased the porosity of the subsequently applied nickel coating.

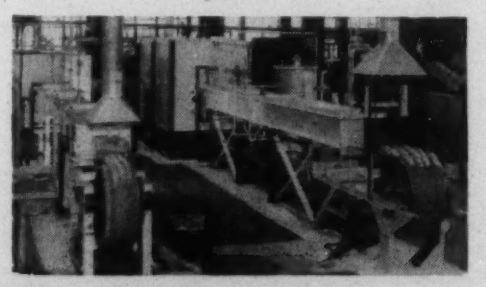
[*These results should be compared with those of a similar study by Pinner reported in our October, 1940, issue, p. 556. Pinner also found fine-abrasive polishing to be better than coarse, but apparently didn't investigate buffing.—F.P.P.*] AB (2)



The operator assembles the parts and places them on the furnace conveyors.



The assemblies are discharged at the other end . . . all units securely and neatly joined.



The satisfactory results from the first furnace at left sold the larger furnace at right.

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2a. Ferrous

Repair Welding of Dies

"Welded Dies; Their Design and Fabrication." A. R. Butler (Welding Equipment & Supply Co.) *Steel*, Vol. 107, Oct. 14, 1940, pp. 106, 108, 136; Oct. 21, 1940, pp. 62-63, 66; Oct. 28, 1940, pp. 66, 68-69. Practical.

Hard-facing at critical points affords important economics in making new dies and in repairing old. By this means it is possible to secure results that cannot be obtained otherwise. Experience has shown that repaired dies often out-perform original metal.

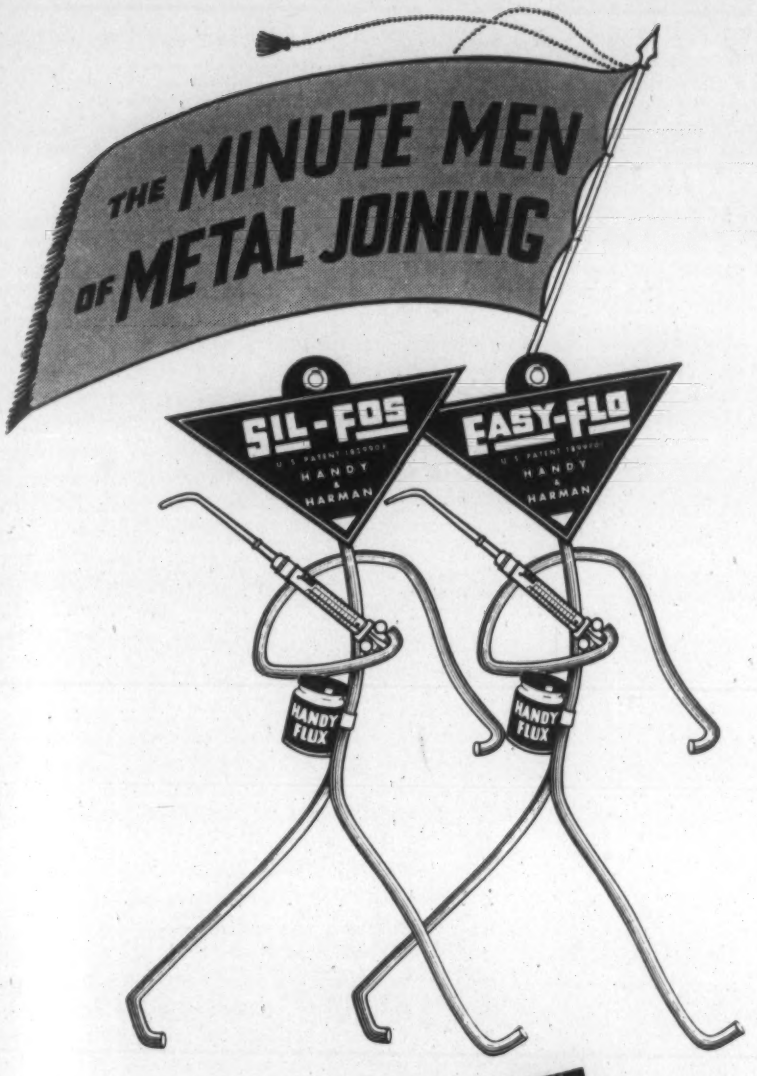
To determine the best method of welding, a study was made of the microstructures and hardness of various hard-facing deposits applied by metallic arc, atomic hydrogen and gas welding. Materials used were water-, oil- and air-hardening tool steels. The results indicated that metallic arc welding is the best method; the hardness and structure of this type of weld approach those of a base metal of similar composition.

Water-hardening tool steel electrodes of the proper type will produce a deposit comparable to the best carbon-vanadium water-hardening steel and will take a typical water-hardening heat treatment. Ultimate hardness of 58-60 Rockwell C can be obtained. Oil-hardening tool steel electrodes of the proper type will give a deposit having the properties of a typical non-deforming, non-shrinkable steel. They are especially adaptable for making repairs, regardless of the type of steel used in the original die. Ultimate hardness of 60-62 Rockwell C can be obtained, depending somewhat on the type of underlying steel. Air-hardening tool steel electrodes will give a typical air-hardening deposit with ultimate hardness of 60-61 Rockwell C.

Hot-work electrodes will give a self-hardening deposit with ultimate hardness of 54-56 Rockwell C by keeping the parent metal below the draw temperature of 1000° F. The deposit air hardens, does not scale excessively, does not fire check, and resists erosion. These electrodes are used with all types of hot-work steels, such as those for dies for die casting aluminum alloys.

A special electrode is recommended for all types of cast iron and medium-hard steel drawing and forming dies and on all sharp contours. The deposit has a hardness of 240-260 Brinell as welded, and will work-harden in use. It is austenitic, will not pick up metal, and takes a high polish.

In applying a metallic-arc tool steel electrode to any type of tool steel, the following recommendations should be observed:



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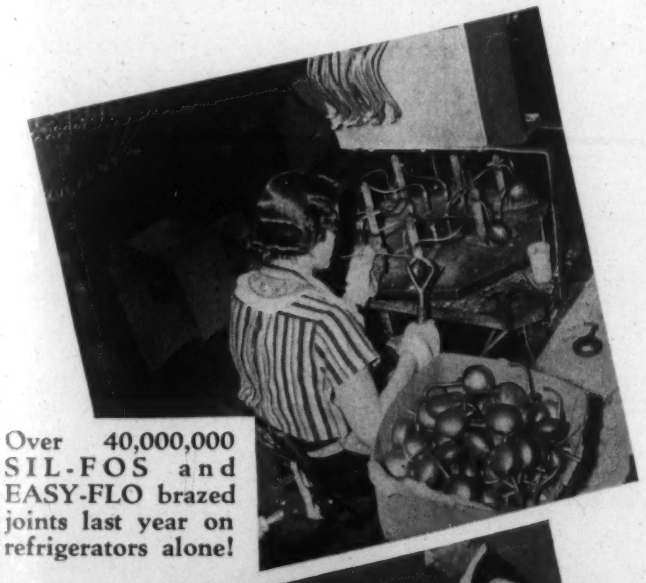
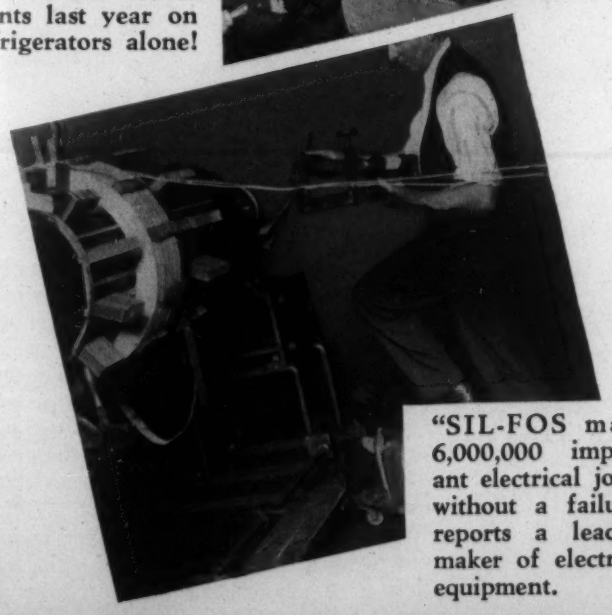
The features that account for the speed and reliability of Sil-Fos and Easy-Flo also make brazing with them one of the most economical methods of joining metals. Low working temperatures, instant penetration, the small amount of alloy needed, little, or no finishing expense, all combine to **save labor, heat and materials.**



Over 40,000,000 SIL-FOS and EASY-FLO brazed joints last year on refrigerators alone!



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The base metal must be preheated to just below its draw range. In welding cutting edges, the electrode should be held favoring the top working face to allow the deposit to flow over the cutting edge. To eliminate deep craters and searing of sharp edges adjacent to the weld area, the arc should be pinched off or the electrode lowered gradually. To eliminate deep craters and sear marks at the extreme ends of the deposit, the welding bead should first progress in one direction to within a short distance of the other end of the worn edge. The bead should then progress in the opposite direction and overlap the first bead.

In welding deeply damaged cutting edges or draw surfaces, start at the bottom and gradually fill up the damaged area, using a slightly higher amperage on the first two beads than on the finishing beads. Sometimes a mild or a typical high-carbon steel can be used as filler, with the actual working edge of tool steel. If possible, reheat after welding to just below the draw range of deposited metal. Electrode size is governed by the width and depth of the damaged section.

Where no preheating is possible, air- or oil-hardening steels should not be used unless the parent metal is in the annealed state. Extremely intricate-shaped sections should generally be avoided. Welding of cast iron dies with any electrode except those specifically recommended for this purpose will give poor results. MS (2a)

Preparing Surfaces for Enameling

"Theory and Practice of Wiping between Phosphatizing and Enamelling." E. E. Halls. *Sheet Metal Inds.*, Vol. 14, Oct. 1940, pp. 1097-1098, 1100. Practical.

There has been considerable disagreement as to whether the loose powdery superficial deposit formed in phosphatizing should be removed before enameling. The 2 main methods of phosphatizing are (1) immersion, and (2) spray.

The immersion process uses 3 vats for the phosphate solution (composition is usually acid phosphates with accelerators) and 2 rinses (the second is generally a weak chromic acid solution), all operated hot. During the formation of the iron phosphate coating, a sludge is formed. The loose deposit found after the treatment consists of this sludge combined with loose dirt, deposit from hard water, etc. The amount of the deposit is less for short immersion periods and for carefully controlled operation where tanks are cleaned regularly.

In the spray method, the work is carried rapidly through zones in which there are batteries of sprays fed with (a) weak alkali; (b) water; (c) phosphate solution; (d) water; and (e) weak chromic acid. The deposit exists as an almost imperceptible film.

Apart from the poor appearance of the article due to the deposit, it may adversely affect the finish. A small amount of deposit prevents the first enamel coating from wetting the surface, but this in itself has no deleterious effect on adhesion. It is the flotation of the loose deposit in the enamel surface that gives an irregular finish, even if the amount of deposit is slight—unless a built-up stoved finish is used, in which case the effect of the deposit is eliminated in the intermediate operations.

Salt spray tests on (1) untreated, enameled sheet; (2) phosphatized, enameled sheet; and (3) phosphatized, wiped, enameled sheet showed that although wiping was not essential, it did provide an extra safeguard for more severe service. The author concludes that the film can be ignored with properly controlled spray and with very rapid immersion (3 min.) treatment. Relatively heavy deposits should be wiped in all cases before finishing. With intermediate immersion periods (5-10 min.), the film can be ignored for built-up or multicoat finishes, but should be removed by wiping for single coat applications.

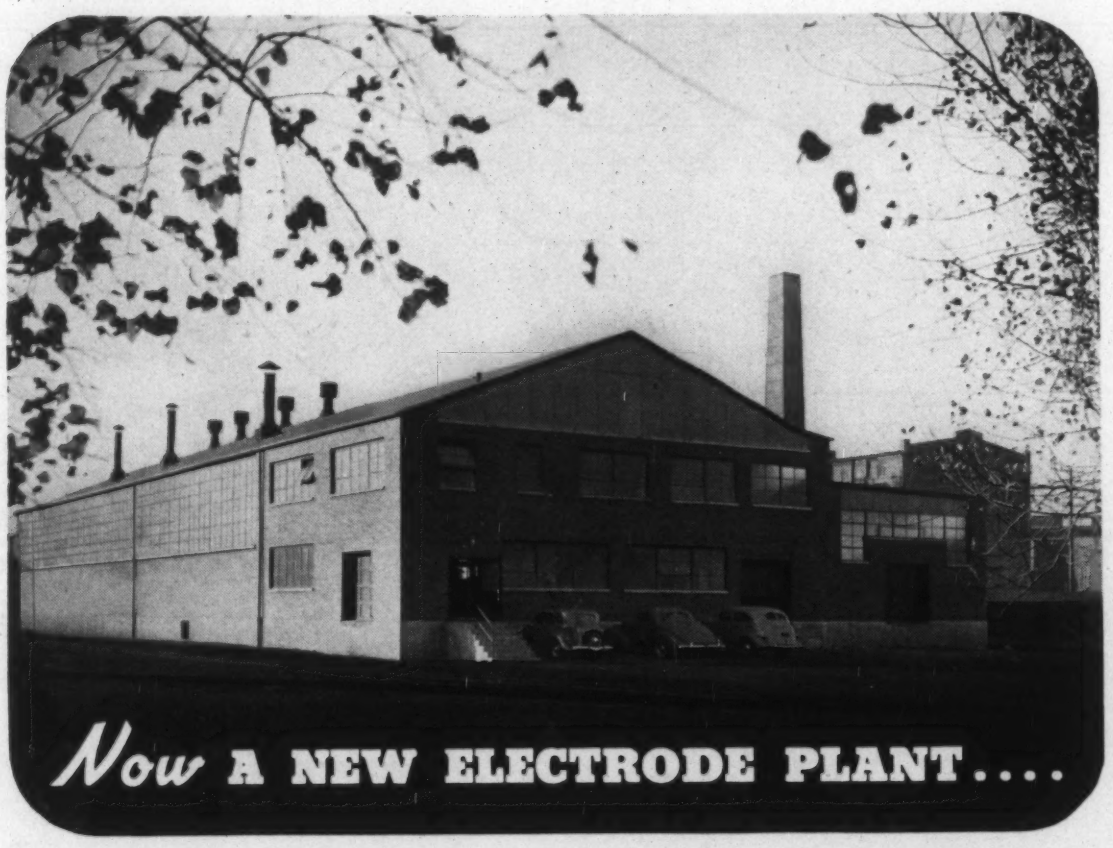
JZB (2a)

Acetylene Welding Light Aircraft

"Oxy-Acetylene Welding of Light Aircraft." Hanford Eckman (Piper Aircraft Corp.) *Paper, Am. Welding Soc.*, Oct. 1940 meeting. Practical.

The light plane is one that has an engine of 75 h.p. or less, and which has a high ratio of weight to power (power loading) and a low ratio of weight to wing area (wing loading). The present light plane is largely a handmade product, and in its manufacture welding plays a prominent part. This discussion is confined to the use of oxy-acetylene welding for light planes for private use.

The welding of light-walled tubing is practiced most extensively in the fabrication of fuselages. Welded tubular design has a high strength/weight ratio, permits a high rate of production with a minimum of special tools and jigs, and provides satisfactory rigidity. Oxy-acetylene welding speeds production, beginning with the fabrication of jigs and continuing through the fabrication of the entire fuselage of



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Designed and built expressly for the manufacture of arc welding electrodes, this up-to-the-minute factory is equipped with the most modern facilities available for the efficient production of electrodes of high quality and absolute uniformity. Its operation supplements that of the original Murex plant at Jersey City, N. J., and more than doubles the output of Murex.

Located close to sources of raw materials and in the heart of the busy mid-western industrial area, the new plant with the additional production capacity it provides, assures better service and more prompt deliveries to Murex customers throughout the country.

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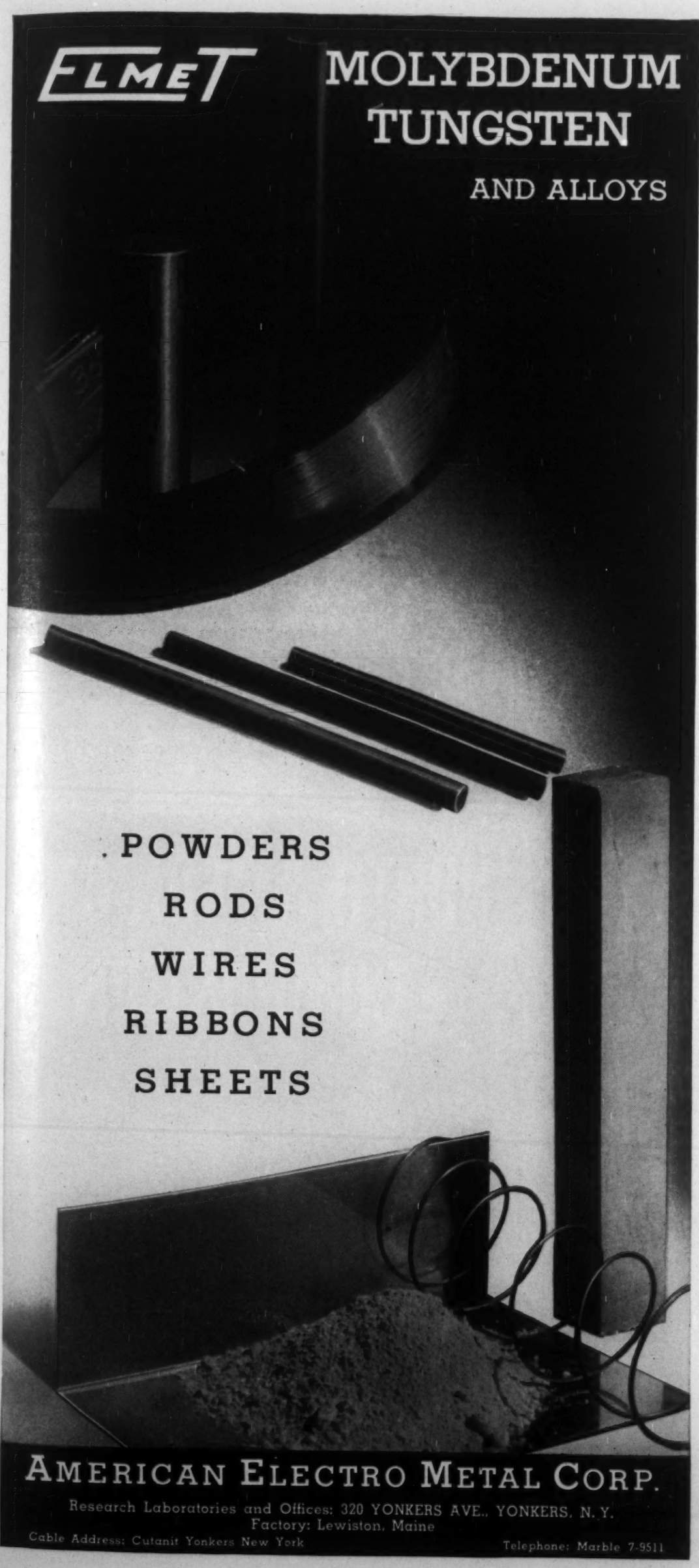


chromium-molybdenum steel (X4130) tubing, and hundreds of small component parts, fittings and subassemblies.

The various "metallurgical" factors that must be considered in welding carbon steels become of even greater importance in welding alloy steels, and particularly in welding light-walled chromium-molybdenum steel tubing. The welding temperature should be the lowest possible and the time period in which the steel is above the critical should be a minimum. Decarburization must be avoided.

Plain carbon steel welding rods of high manganese and high silicon contents (to react with iron oxide in welding) can have high carbon contents, and the resultant welds in chrome-moly tubing are clean and fairly strong. Neutral flame adjustments are used and excessive melting of the base metal is not necessary.

Better, though, is the newer process known as "excess acetylene welding," which is especially applicable to the welding of chrome-moly tubing. Using standard oxy-acetylene welding equipment, the flame is adjusted and manipulated to give an excess of acetylene over the oxygen required for complete combustion. As a weld progresses carbon is absorbed from the flame on the surface of the steel and the blowpipe is so manipulated that the carbonaceous film covers the base metal adjacent to the welding puddle.

The high carbon surface film melts spontaneously as the carbon content approaches the eutectic (4.5%) value, and then mixes with the weld metal in a sort of "self-fluxing" action (since it also prevents oxidation and reduces oxides). In addition, "excess acetylene" technique speeds up fabrication, permits welding at a lower temperature, reduces grain growth, is adaptable to both forehand and backhand technique, and eliminates decarburization of the tubing surface at the weld. (2a)

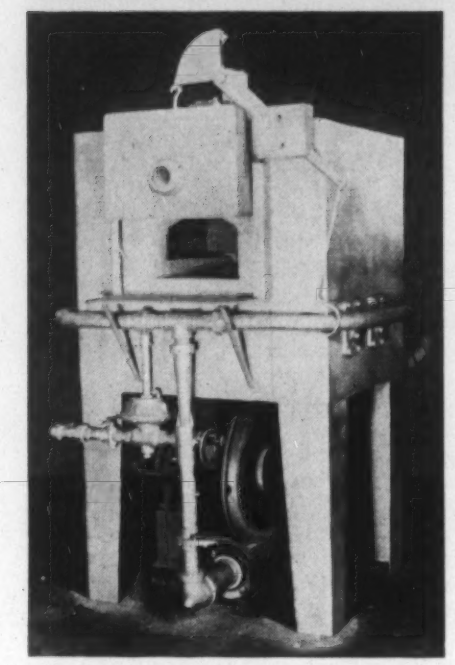
Tempering High-Carbon Steels

"Effects of Small Amounts of Alloying Elements on the Tempering of Pure Hyper-Eutectoid Steels." Charles R. Austin & B. S. Norris (Penn State) *Preprint, Am. Soc. Metals,* Oct. 1940, 24 pp. Research.

The paper deals with the softening characteristics of 1.1% C steels made from electrolytic iron melted under hydrogen in an induction furnace and containing 0.5% or less of one of the following third elements: Manganese, silicon, nickel, chromium, copper, aluminum, sulphur, phosphorus or tin. The steels were hardened and subsequently tempered for a period ranging from ½ to 125 hrs. at 5 different temperatures: 1020°, 1095°, 1165°, 1240° and 1310° F., the reaction to heat treatment being followed by metallographic and hardness tests.

An approximately linear relationship exists between either Rockwell "B" or Brinell hardness and the log of tempering time up to 125 hrs. so long as graphitization does not occur. Profound graphitization was found in some of the aluminum steels when tempered at 1020°, 1095° and 1165° F. [*See also the digest "Graphitization in Steels" on p. 788 of the Dec. 1940 issue.*] In the alloys with 0.5% Mn, Si, Al or Cu, after a tempering period of 1 hr. at any of the above temperatures, a hardness value from 10 to 30 Brinell units greater than that for the plain carbon steel was obtained.

For chromium, the values were 70-100 units higher, whereas nickel appeared to have little effect. When the quantity of added element is 0.07-0.08%, only small differences existed between the hardness of



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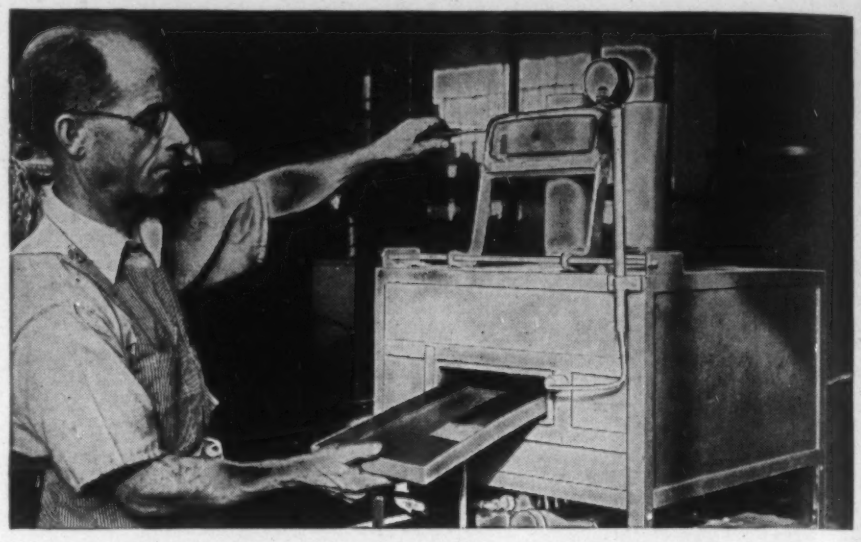

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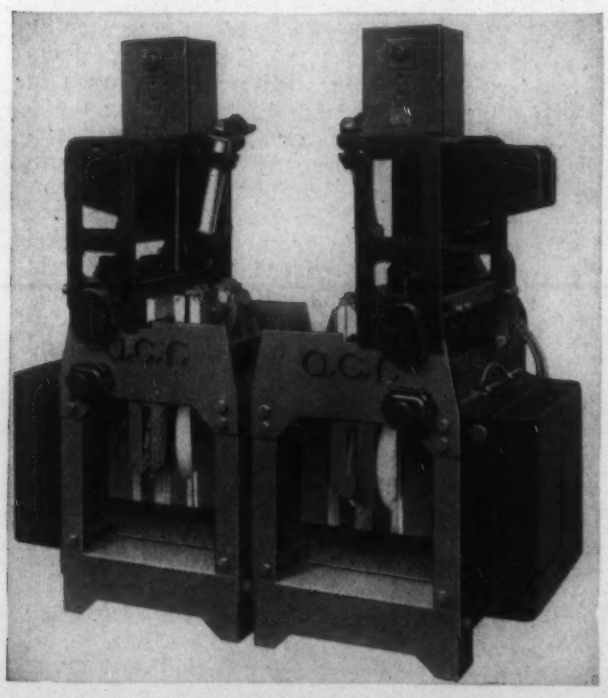

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the alloys and that of the carbon steels after 1 hr. temper in the range studied. The effect of chromium, however, even in such small amounts, was noteworthy.

Curves are presented to show the variation in rate of softening at 1310° F., with different alloying element. This analysis reveals the relatively minor effects of added element up to 0.08%, but it clearly demonstrates that for about 0.5% of element present, manganese, nickel and aluminum cause only a small increase in resistance to softening, while copper, silicon and chromium show increasingly marked effects in the order listed. At all temperatures investigated, the relative rate of softening at any selected Brinell hardness was very much greater for the nickel than for the chromium steel. The nickel steels behaved like the plain carbon steels. EF (2a)

countered after a short time. Small alloying additions, such as 1% Cd or 1% Ag, increase the recrystallization temperature and therefore decrease the tendency to soften. Mixtures of copper and tungsten have been widely advocated but are little used in England at the moment. Some of the complex sintered or heat treatable alloys have suitable properties, but are too expensive for ordinary work.

Pick-up, that is, fouling of the tips by adhering particles of metal, oxide, etc., necessitates cleaning of the tips after 20-300 welds to prevent overheating and corrosion in service. The surface of the sheet being welded is also important in this connection, as rough surfaces increase pick-up. The operator must look out for signs of burning or dark spots. Best cleaning is by means of fine emery cloth. Mushrooming or deformation of the tip due to heat and pressure requires accurate turning of the tip.

In a second article the same author ("Machines and Their Operation for Welding Aluminum-Rich Alloys," *Ibid.*, Oct. 1940, pp. 1103-1106, 1108) discusses Philip, Taylor-Winfield, Skiaky and other spot welding systems. Generally speaking, the machines used fall into 3 groups: a.c. in secondary circuit, single impulse of unidirectional current, and "program-controlled" types.

In a.c. machines, high currents, high capacity transformers and ample cooling are required. Welding current and time are generally controlled by thyratron or ignitron systems. The condenser type of plant (Philip or Taylor-Winfield type) stores the electri-

2b. Non-Ferrous

Spot Welding Aluminum Alloys

A Composite

If looking at a new airplane brings spots before your eyes, don't worry—it's just a sign of these spot-welded times. Since modern equipment has surmounted the critical problems associated with the high conductivity and low melting points of the aluminum alloys, every aircraft metallurgical engineer designing in aluminum is either interested in or actually using spot welded fabrication. Two recent articles by *Sheet Metal Industries'* ubiquitous "Agricola" review the operating problems encountered, and describe the latest spot welding equipment used with aluminum alloys.

In the first of these, "AGRICOLA" ("Spot Welding of Aluminum Alloys," *Sheet Metal Inds.*, Vol. 14. Sept. 1940, pp. 992-994, 996, 998) reviews some of the now-familiar points—the need for higher currents because of aluminum's high conductivity, for more precise control because of the low and narrow melting range, for uniform surface conditions, for control of temper to obtain proper sheet contact, for consideration of likelihood of softening of metal near weld, etc.—and goes on to suggest satisfactory practice.

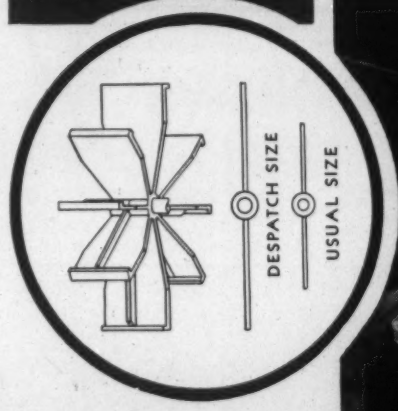
Changes in current strength have a greater influence on the strength of a weld than any other single factor, probably due to the effect on the size of the spot. Although the strength increases linearly with the current, excessive current may lead to porosity and cracking.

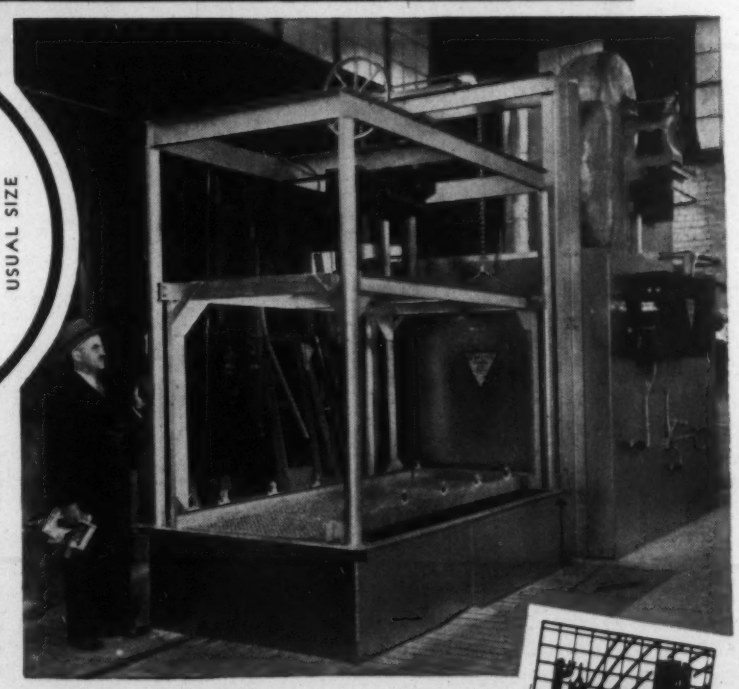
If current and pressure are carefully controlled, the time period does not need to be less than about 0.1 sec. Very short time periods give porous welds and possibly cracks; then there is a rapid increase of strength with further increases of time until a point is reached at which further increases in time do not appreciably alter shear values; excessive times may give coarse structures with increased segregation or precipitation as well as increased distortion.

Pressure affects the depth of the impression, the porosity of the weld, and the tendency for metal to be exuded between sheets, but its influence on strength is not appreciable within fairly wide limits. Pressure is generally proportional to the thickness of the sheets welded, but does not vary appreciably with composition.

Electrodes must resist deformation, wear and softening; further, they must have no tendency to alloy with the sheet. Since at least 85% electrical conductivity is required, many prefer hard drawn electrolytic copper, but appreciable softening is en-

Attain New Heat Treating Uniformity
FOR FERROUS AND NON-FERROUS METALS





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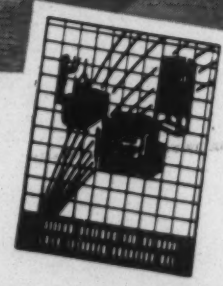

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MINNEAPOLIS MINNESOTA

cal energy by means of a condenser system. The Skiaky system uses direct current derived from a.c. by a mercury arc rectifier, and energy is stored inductively. This machine also has a variable pressure cycle with the initial pressure almost double the welding pressure to break down the oxide film, and followed by increased pressure after welding to forge the plastic metal, although the pressure falls to zero as the tips open. [For additional information on the Skiaky machine, read the digest "Stored Energy Spot Welding," on p. 673 of our November issue.]

Sheets must be degreased before welding and the film must be removed mechanically (with emery) or, preferably, chemically (in an acid pickling bath or with a paste etch containing hydrofluoric acid). Spacing of the spots must not be left to the operator but must be laid down in the original design. It is not possible to set up exact welding conditions due to the many variables, and trial settings are necessary before actual production starts. Radiography will show up gross porosity or severe cracking, although mechanical and macrographic tests are more common. JZB (2b)

Gold Plating

"Art of Gold Plating." Fred B. Jacobs. *Steel*, Vol. 107, Oct. 7, 1940, pp. 59, 62. Description of practice of Ohio Plating & Mfg. Co., Cleveland.

Proper preparation of the surface of the article is essential. If the article is to be refinished and is nicked or scratched deeply, it is first polished with No. 180 emery, set up on a stitched muslin or felt wheel. These wheels are 3-6 in. in diam. and are run at a surface speed of 5000-6000 ft./min.

If the article is not dented or scratched deeply, it may be buffed on a loose muslin wheel, with tripoli applied to the wheel in cake form. Then the work is buffed on a loose muslin wheel with cake white lime applied locally. These wheels are usually run somewhat faster than those mentioned above. The article then is treated successively by a dip into a solution of sodium silicate, sodium hydroxide and sodium cyanide, followed by a 10% hydrochloric acid bath, washed in cold water, wire-brushed with a nickel silver rotary brush, rinsed in cold water, dipped in a sodium cyanide bath, and rinsed in cold water.

The work is now ready for plating. Generally, the plating tank holds about 50 gals. of solution containing gold and cyanide. The anode is 27-carat fine gold, alloyed with copper, and is about 4 in. long, 1 in. wide and 1/16 in. thick. The thickness of coating applied seldom exceeds 0.00075 in. and requires about ½ hr. at 2 volts and current-density of 10 amp./ft.^{2}

If a dull finish is desired, the article is brushed with a revolving nickel silver wire brush. For a lustrous finish, the work is color-buffed on a canton flannel buff, 3-6 in. in diam., with stick rouge.

In addition to the gold plating of ecclesiastical goods, jewelry, etc., there are a number of important commercial uses for gold plated articles. An example is the gold plated reflectors used with infrared lamps employed in drying lacquer. Another is the plating of the inside of brass tubing used for conveying oil from cottonseed presses. Gold plated surfaces do not corrode and they eliminate the objectionable fumes formerly present in the extraction process.

In plating these tubes, both ends of the tube are corked and the anode, a 1/16-in. diam. gold wire, extends through the corks and through the entire length of the tube. The tube is filled with the plating solution and thus forms its own tank.

MS (2b)

Indium Plating

"Electrodeposition of Indium from Sulphate Baths." Colin G. Fink & Raymond H. Lester (Columbia Univ.) *Trans. Electrochem. Soc.*, Vol. 78, 1940, Preprint No. 14, 23 pp. Research.

The high purity of zinc required for die castings has necessitated the removal of impurities, among them being indium. Although larger quantities of indium are available than formerly, the price is still high—$240 per oz. Uses are fast being developed and many of them, particularly those of indium plating, have important industrial possibilities.

Indium is deposited from an acidified solution, about 0.26 *M* in indium sulphate, with a current efficiency of 35%. Boric acid increases this to 45%. These deposits are coarsely crystalline and unsatisfactory. Addition of aluminum sulphate improves the quality of the deposits. Gelatin still further increases their smoothness, but lowers the current efficiency about 20%.

The most satisfactory plating bath contained 0.10 *M* In_2O_3; 0.30 *M* H_2SO_4; 0.0173 *M* $Al_2(SO_4)_3$; and 0.0075 g./l. of gelatin. The current density is 3.3 amps./dm.^{2} and the temperature is 26°C. (79°F.) The current efficiency is about 35%.

AB (2b)

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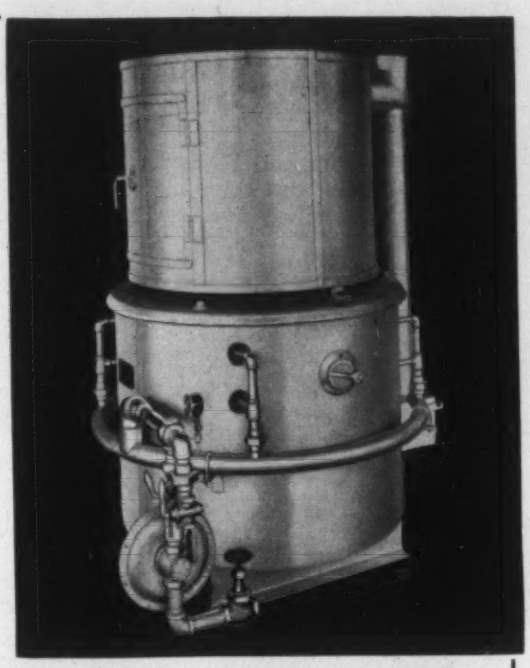

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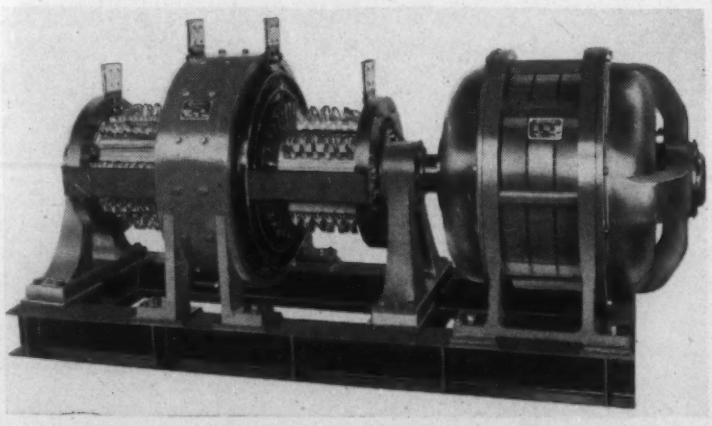

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Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

Fatigue Strengths and Surface Conditions

A Composite

At the October meeting of the Am. Soc. for Metals papers were presented on the effect of surface conditions on fatigue strength: (1) "Chafing Fatigue Strength of Some Metals and Alloys," by G. SACHS & P. STEFAN of Case School of Applied Science; (2) "Effect of Surface Conditions on Fatigue Properties," by O. J. HORGER & H. R. NEIFERT of the Timken Laboratories; (3) "Shot Blasting and Its Effect on Fatigue Life," by F. P. ZIMMERLI of the Barnes-Gibson-Raymond Div., Associated Spring Corp.; and (4) "The Fatigue and Bending Properties of Cold Drawn Steel Wire," by H. J. GODFREY of Lehigh Univ.

HORGER & NEIFERT had profilograms of the surfaces of their specimens showing the depth and shape of the minute "notches" left by different surface finishes. The depth of notch thus shown did not show any clear correlation with reduction in fatigue strength (endurance limit). A specimen of S.A.E. 1045 steel given a "superfinish" showed slightly lower fatigue strength than a specimen with a polish with 000 emery. This result is in harmony with Zimmerli's finding that maximum smoothness of surface alone does not insure maximum fatigue strength for a given metal.

"Chafing" Fatigue of Machine Parts

SACHS & STEFAN made fatigue tests on rotating-beam specimens held in a special chuck and without reduced section. This resulted in most failures taking place in, or at the edge of, the chuck, and a rubbing action which the authors call "chafing" fatigue, with a reduction of the fatigue strength well below that of the ordinary polished specimen with reduced section. Probably the action that takes place in an axle at the edge of the hub of a pressed-on wheel is this chafing fatigue, and Horger's values reported for axles with pressed-on or shrunk-on wheels may thus be regarded as further data on chafing fatigue.

Metal in a relatively stable condition (annealed or at least stress-relieved) showed higher fatigue strength than did cold-worked or heat-treated metal. "Chafing" fatigue increased its damaging power with increase in the number of cycles of stress. Some tests running to about 100,000 cycles showed as long "life" for "chafing" specimens as for "regular" fatigue specimens (specimens with reduced section). SACHS & STEFAN also made tests on cast metal and found that while, in general, both "chafing" and "regular" fatigue strength is lower for cast than for rolled metal, yet the ratio of "chafing" to "regular" fatigue strength was higher for cast metal than for rolled.

HORGER & NEIFERT's tests on specimens with pressed-on or shrunk-on wheels showed slightly higher fatigue strength for an axle specimen with "superfinish" on the wheel seat than for one with smooth-turned finish. An axle specimen with a shrunk-on wheel showed lower fatigue strength than one with a pressed-on wheel. HORGER & NEIFERT reported that cold rolling of an axle surface was more effective in increasing fatigue strength under the "chafing" action of a pressed-on wheel than smooth turning, grinding or polishing.

In one test of axle specimens with pressed-on wheels, rolling the wheel seat increased the fatigue strength 150%. In another test of axle specimens (1045 steel normalized and tempered) the wheel seat was sprayed with a coat of 1.20% C steel 1/16 in. thick, and the fatigue strength was increased 61% over that of the uncoated steel, whose fatigue strength was 13,000 lbs./in.^{2} By means of flame hardening, this value was increased to 45,000 lbs./in.^{2}

Improving Wire Fatigue Strength

ZIMMERLI discussed especially the use of shot blasting to improve the fatigue strength of spring steel wire. He maintained that shot blasting has done more to increase the "life of small springs than any of the alloying elements used in steel." Shot blasting may be done by an air-blast blowing small shot against a surface, or by throwing small shot against a surface by centrifugal force from the blades of a rapidly-rotating wheel.

ZIMMERLI described a mechanically-

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operated testing machine on which 8 small springs may be given fatigue tests at one time. He reports values of endurance range for springs made of various kinds of wire that show valve spring wire, for example, to have its "*not*-shot-blasted" endurance range of 20,000-95,000 lbs./in.^{2} raised to 20,000-135,000 lbs./in.^{2} when shot-blasted.

Tempered spring steel has a sorbitic structure, and even under 1500 X magnification ZIMMERLI could not determine the starting point of a fatigue crack. Using softer shot than usual, the shot-blasted surface looked smoother, but the spring had no greater fatigue strength than that shot-blasted with the harder shot. This is in harmony with the findings of HORGER & NEIFERT. ZIMMERLI concludes, in view of the improvement that can be made in surface conditions by shot-blasting, and by other mechanical means, that "the use of alloy steel, from a fatigue point of view, is not necessary in fabricating many parts." This too seems in harmony with the findings of HORGER & NEIFERT.

H. J. GODFREY discussed fatigue tests of cold-drawn steel wire, on a modified Haigh-Robertson machine, and also bending tests on a hand-operated machine that gave 180-degree bends to specimens of wire, over rollers of various diameters. The bend-test results he used as an index of the ability of the wire to withstand a relatively few severe bends without fracture.

GODFREY reported test data indicating that the fatigue strength increased with cold work, with a tendency for the "fatigue ratio" (ratio of fatigue strength to tensile strength) to diminish as the tensile strength increased. The fatigue ratio was also found to decrease as the carbon content of the wire increased. An electro-galvanized coating did not lower the fatigue ratio of a wire with decarburized surface. However, the fatigue ratio for wires with decarburized surface was found to be about 0.24, while for wires with non-decarburized surface it was 0.33. Polishing a wire increased its fatigue strength slightly.

From his bend tests GODFREY found that for wire lead-quenched from above the critical to 900-950°F. the number of 180° bends for fracture increased with cold work up to about 60% reduction. X-ray studies of the atomic structure of wire showed that under cold work the tendency to preferred orientation was more pronounced in the interior of the wire than at the surface.

[*These four papers emphasize strongly the importance of surface conditions in connection with the fatigue strength of structural and machine parts. They show the possibility of markedly increasing that fatigue strength by proper surface treatment—polishing, rolling, shot-blasting, metal spraying, flame hardening and cold drawing. They also emphasize the necessity of considering the "chafing" fatigue often found in machine parts. There is a fast-growing conviction that endurance limits based on tests of small polished specimens are not sufficient as a basis for design, and this means that probably forms of fatigue-testing machines in which surface effects can be studied—vibratory or axial-stress machines for example—will be more and more used in the future.*—H.F.M.] HFM(3)

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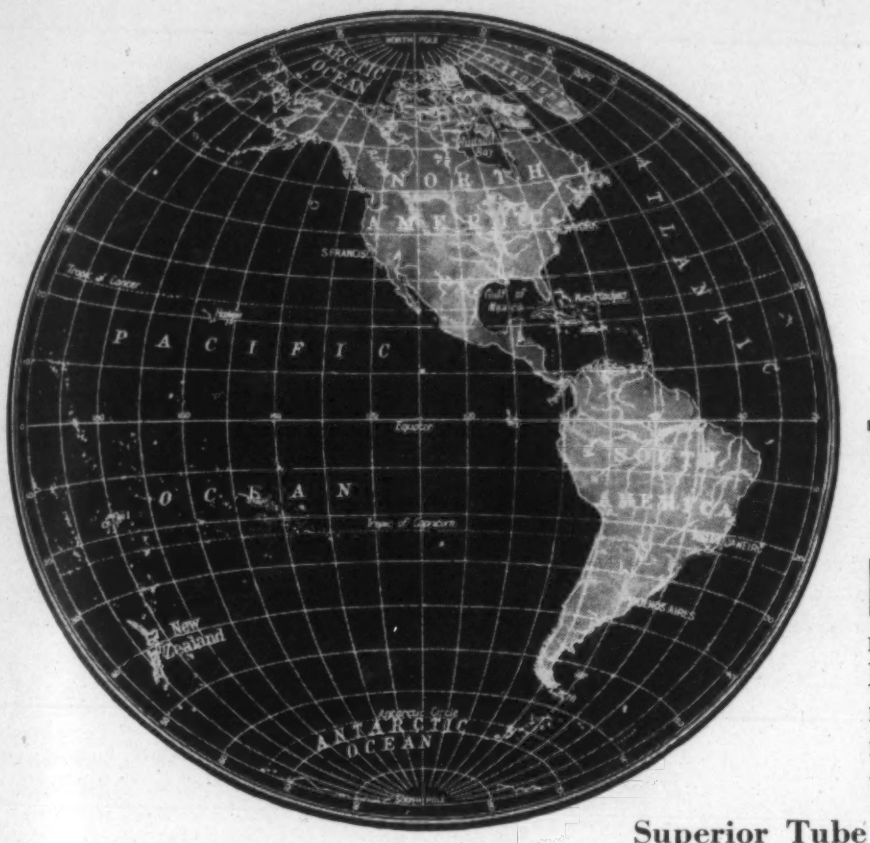
Nitric Acid Corrosion

"THE STUDY ON THE CORROSION RESISTANCE OF METALS TO THE NITRIC ACID SOLUTION." YOICHI YAMAMOTO. *Sci. Papers Inst. Phys. Chem. Research, Tokyo*, Vol. 37, Mar. 1940, Abstract Supplement pp. 15-17. In English. Original research.

The effect of nitric acid on magnesium, aluminum, chromium, manganese, iron, cobalt, nickel, copper, zinc, molybdenum, silver, cadmium, tin, antimony, tantalum, tungsten, platinum, gold, mercury, lead, bismuth, carbon, silicon, piano wire steel, 13% Cr-steel, 18/8 stainless, 70/30 brass, Monel metal, and 80/20 nickel-chromium alloy was investigated by 3 methods: (a) By determining the degree of attack, (b) by measuring the electrode potential, and (c) by observing the action of these materials as anodes during electrolysis of nitric acid.

Any corrosion resistance observed was found to be due to the protective action of a coating of more or less stable oxides. Protection is assured by metal oxides in which the metal has a valency of 3, 4, 5 or 6. The protective coating that forms on the surface of aluminum, gold, chromium and platinum is the oxide corresponding to a valency of 3; on silicon it is the oxide of valency 4, while oxides corresponding to valencies of 5 and 6 are formed respectively on tantalum and tungsten. Iron is violently dissolved in nitric acid solutions due to the formation of the oxide of valency 2, but it becomes passive in concentrated nitric acid due to the formation of a trivalent oxide. The appearance of passivity of iron in concentrated nitric acid is due to the formation of nascent oxygen through electrolytic decomposition of nitric acid. Nickel and molybdenum resist concentrated nitric acid because the trivalent oxide is formed through the decomposition of nitric acid.

The dissolution velocity of a metal that



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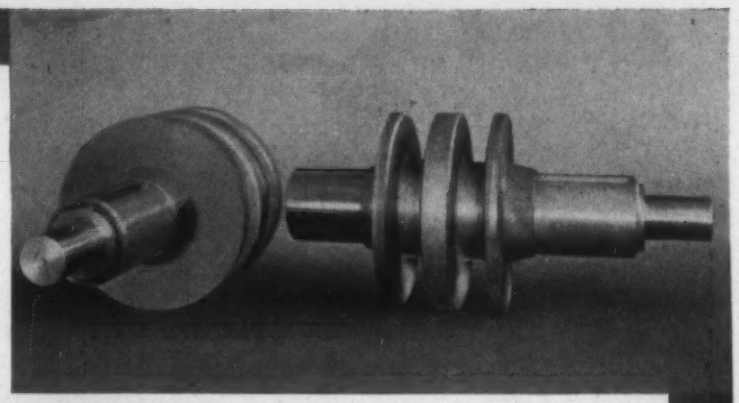

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Chromium, tantalum and tungsten are resistant to all concentrations of nitric acid, hot or cold. The 12% Cr iron alloy showed good corrosion resistance. The corrosion resistance of iron-chromium alloys with more than 12% Cr was better than that of nickel-chromium alloys with more than 11% Cr. EF (3)

Metals for Sprayer Nozzle Disks

"Wear in Sprayer Nozzle Disks." C. N. Turner (Cornell Univ.) *Agricultural Eng.*, Vol. 21, Oct. 1940, pp. 393-394, 405. Investigation.

Three different tests were run to determine the relative wear of different metals used as sprayer nozzle disks. The first 18 hrs. of the first test were run with a mixture of 2 lbs. wettable sulphur, 1 lb. lead arsenate, 2 lbs. hydrated lime and 25 gals. water. The last 12 hrs. of the first test were run with a Bordeaux mixture of 2 lbs. copper sulphate, 2 lbs. hydrated lime and 25 gals. water. The pressure at the nozzle throughout the test was 380 lbs./in.^{2} Disks were changed in the broom head progressively from one end to the other every 5 hrs., so that no disk would have an advantageous position in the broom. Disks used in this test were (1) standard Hardie [composition not indicated], (2) "as-rolled" cold-rolled, fully hard "K" Monel, (3) as-rolled, fully hard "Z" nickel, and (4) as-rolled, fully hard Inconel.

The second test was run with a double-strength Bordeaux mixture of 4 lbs. copper sulphate, 4 lbs. hydrated lime and 25 gals. water. The pressure at the nozzle was the same as in the first test. The disks used here were (5) cold-rolled 18-8-S Mo stainless steel type 316, No. 2 finish, (6) cold-rolled 17-7 stainless steel, type 301-X, No. 2 finish, (7) 12% Cr stainless, type 410, No. 1 finish, and Inconel (No. 4 above) again.

The third test was run with the same Bordeaux mixture as in the second test, but the pressure at the nozzle was increased to 460 lbs./in.^{2} The disks used were (6), (8) cold-rolled 12% Cr stainless, type No. 410, (9) heat-treated, cold-rolled, full-hard temper "K" Monel, and (10) heat-treated, cold-rolled, full hard temper "Z" nickel. The second and third tests were run for 26 hrs. each, with the spray mixture renewed at about 10-hr. intervals. The per cent of increase in the rate of discharge after the test, compared with that before the test, was used as the measure of durability of the disks.

The results indicated that the mixture used in the first part of test 1 caused little wear. Disk No. 1 showed more wear than the others, due in part to corrosion by sulphur. This disk showed severe corrosion throughout both parts of the test.

The single-strength Bordeaux mixture was responsible for most of the wear on disks No. 2, 3, and 4. The double-strength Bordeaux mixture in test 2 caused considerable increase in the rate of wear, even though the test was 4 hrs. shorter. The higher nozzle pressure in test 3 caused still higher rate of wear. This increase in wear occurred even with the resistant metals.

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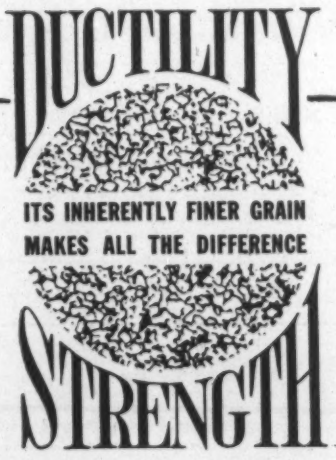

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3a. Ferrous

High-Temperature Design Factors

A Composite

The public's attention was focussed on high-temperature materials not so long ago by the Navy Department's belated sanction of high-pressure, high-temperature boiler systems for the Nation's battleships. High-pressure boiler operation saves fuel, water and storage equipment and thus permits either wider cruising or added armament, but steels safely resistant to creep and high-temperature failure are required.

The Navy was evidently harder to convince that adequately resistant materials were available than is industry generally, for the story of the Navy's boilers has been repeated countless times in the last decade throughout general industry, where creep-resistant materials are judiciously employed to improve efficiency, extend equipment life and decrease costs. Most recently, concerted attention seems to be directed to accumulating creep and rupture data that metallurgical engineers may find still more useful in designing equipment to operate at higher-than-ordinary temperatures.

Creep Strength and Structure

For example, R. F. MILLER, W. G. BENZ & W. E. UNVERZAGT of U. S. Steel Corp. ("The Creep Strength of 18 Low-Alloy Steels at 1000° F.," *Preprint, Am. Soc. Testing Materials*, June 1940, 11 pp.) present a mass of data on the effect of composition and heat treatment on the creep strength of the common low-alloy steels at 1000° F. They found that the creep strength (stress for a creep rate of 0.000001 in./in./hr.) of carbon-molybdenum steels increases with increasing molybdenum content, whether in the normalized or normalized-and-tempered condition (although normalized material was always better than normalized-and-tempered). However, the pearlitic structure resulting from normalizing is unstable at 1000° F., and the lower creep strength of the more stable normalized-and-tempered materials is actually a more conservative estimate of their creep strength.

In fact, stability of structure cannot be overemphasized in evaluating high temperature behavior. Thus chromium additions lower the creep strength of carbon-moly steels (although the decrease may be partially offset by increasing the molybdenum content), but it does increase their structural stability. Addition of titanium or columbium to chromium-moly steel improves its creep strength in the hot-rolled-and-tempered condition, but this improvement may depend on an initial heat treatment giving a structure of unknown permanence.

The essential importance of structure in creep behavior and, incidentally, the utility of columbium, are also strongly emphasized in a paper by E. R. PARKER of Gen. Electric Co. ("The Development of Alloys for Use at Temperatures Above 1000 Degrees F.," *Preprint, Am. Soc. Metals*, Oct. 1940, 11 pp.). A critically-dispersed stable compound offers the maximum resistance to deformation at both low and high tem-

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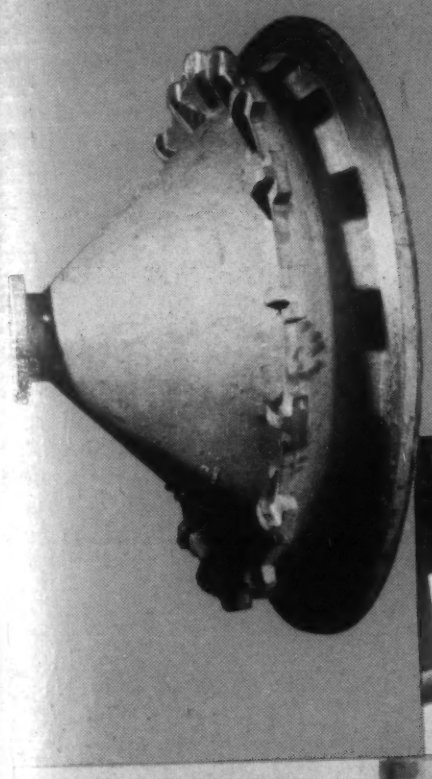

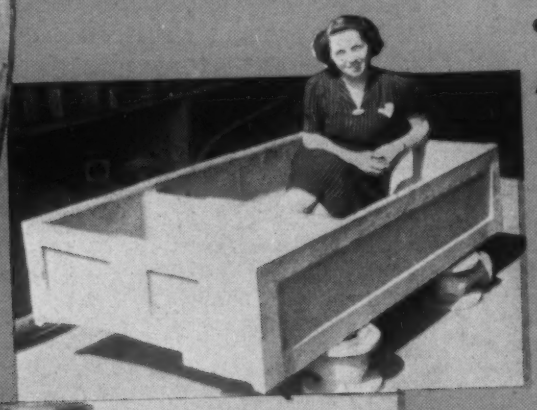

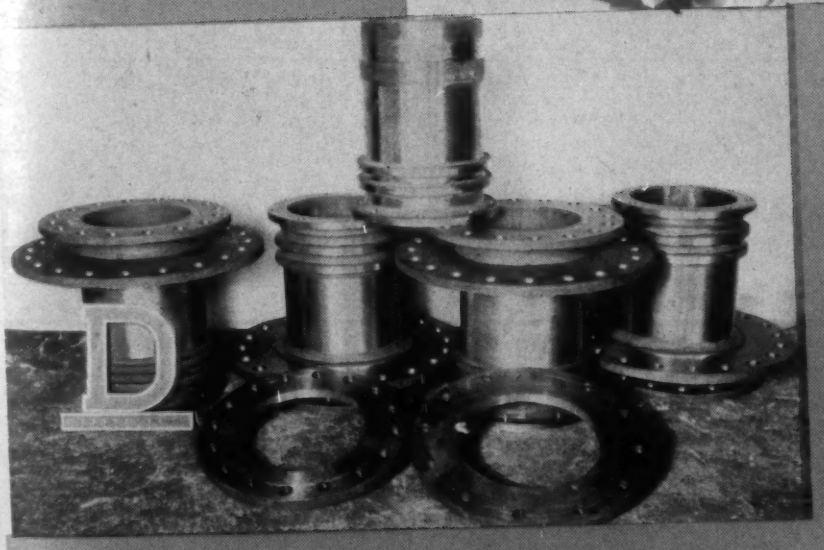

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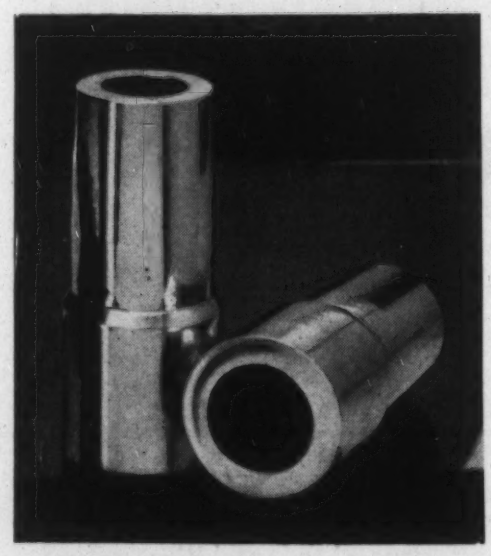

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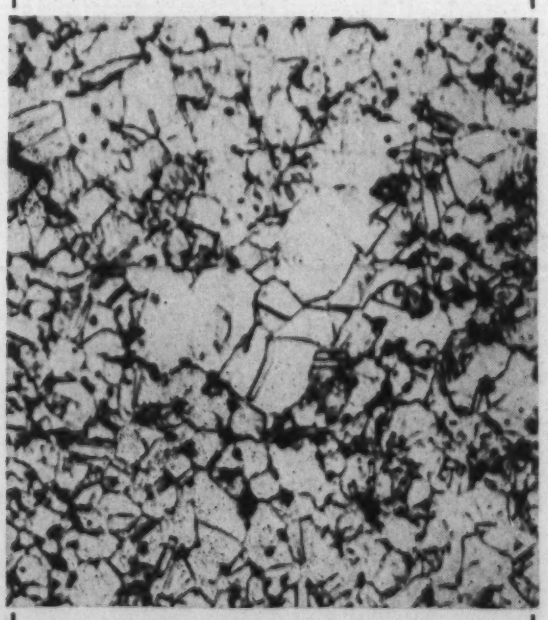

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peratures. Certain intermetallic compounds, like Fe_2Cb_2 and Fe_2Mo_2, are fairly stable at temperatures above 1000° F.; for example, a 3% Cb, 97% Fe alloy had exceptionally good rupture strength at 1100° F., as did an age-hardening alloy containing 15% Mo and 2.5% Ti. The rupture strength of precipitation-hardening alloys can be much greater than steels that depend on carbides for their strength.

In purchasing steel for high-temperature service, General Electric Co. now estimates the creep strength from the composition and microstructure of the steel, according to S. H. WEAVER ("Relation of Grain Size to Creep Strength of Carbon-Molybdenum Steel," *Gen. Electric Rev.*, Vol. 43, Sept. 1940, pp. 357-364). There is reported to be an optimum grain size of each steel which corresponds to the maximum creep strength at each creep temperature. At about 750° F. the finest-grained steel (0.50% Mo) had the greatest creep strength at 1110° F. the coarsest-grained steel had the greatest creep strength; and at temperatures between these, intermediate grain sizes had the greatest creep strength—in continuous progression. Weaver's "grain size" is "the existing predominant grain" in the steel [as observed without any special "austenite grain size" heat treatment].

However, according to A. E. WHITE & SABIN CROCKER of Detroit Edison Co. ("Effect of Grain Size and Structure on Carbon-Molybdenum Steel Pipe," *Preprint, Am. Soc. Mech. Engrs.*, Dec. 1940, 9 pp.), too great an emphasis is being placed on grain size and not enough on the *type* of carbide structure; consideration should be given to both factors, with greater emphasis on the latter. Using carbon-moly steels, no apparent relationship between creep strengths at 925° F. and other significant properties was observed. If, however, the carbide structures are of a Widmanstätten type, with grain size ranging from 2 to 7, the steels will have high-temperature creep properties superior to those in which the carbides exist in other conditions or forms. The steels must be properly killed to attain the desired structure.

Creep vs. Rupture as Design Basis

Just what type of data the metallurgical design engineer should employ is still an unsettled question, but some of the following results tend to bring a little order into the picture. In the first place, a deathblow seems to have been delivered to the continuing use in Germany of extrapolated short-time creep test data for design purposes by A. POMP & A. KRISCH ("Zur Frage der Dauerstandsfestigkeit warmfester Stähle bei 600, 700 und 800° C.," *Mitt Kaiser-Wilhelm-Inst. Eisenforsch., Düsseldorf*, Vol. 22, No. 9, 1940, pp. 137-148). Using chromium-molybdenum, chromium-manganese, chromium-nickel and chromium-cobalt steels, tests up to 1300 hrs. proved conclusively that the short-time test does not give reliable approximate values for creep strength in this range, and that it is even unsuited to a simple comparison of two materials.

High-temperature *rupture* properties as distinguished from *creep* properties are being investigated and used as bases for design. R. H. THIELEMANN of Gen. Electric Co. ("Some Effects of Composition and Heat Treatment on the High Temperature Rupture Properties of Ferrous Alloys," *Preprint, Am. Soc. Testing Materials*, June 1940, 17 pp.) pays particular attention to susceptibility to failure by intergranular fracture in the 900°-1300° F. range. Only the chromium-bearing ferritic alloys were free of intergranular cracking in protracted rupture tests. The austenitic nickel-chromium alloys were especially susceptible.

Brittle fractures of this type may occur with less amounts of extension and at still lower stresses after longer periods of time, states E. L. ROBINSON of Gen. Electric Co. ("High Temperature Rupture and Creep Tests," *Preprint, Am. Soc. Testing Materials*, June 1940, 7 pp.). Rupture results at 1000 hrs. should therefore not be extrapolated to 100,000 hrs.

If creep strengths are chosen with reference to a rate of 0.001% per 1000 hrs. (as with turbines) the 100,000-hr. rupture strength may be 4 or 5 times the creep strength. But if creep strength is chosen with reference to 0.01% per 1000 hr., the apparent long-time factor of safety may be much less. Actually, when treatments are varied the rupture strength is affected much less than the creep strength, and if working stresses are set with reference to a low-creep-strength material, the rupture strength may be 4 times the working stress. On the other hand, if the treatment is varied to improve the creep strength, the rupture strength may turn out to be no more than double the nominal creep strength and some tests show the margin to disappear entirely.

Where the amount of creep is not in itself an important consideration, there is good reason for design to be guided by rupture strength rather than by creep strength. On the other hand, where the amount of extension, distortion, or deflection is of prime importance, both creep strength and rupture strength must be considered.

Obviously, correlation of creep and rupture test results is greatly to be desired, so along comes R. H. THIELEMANN ("Correlation of High Temperature Creep and Rupture Test Results," *Preprint, Am. Soc. Metals*, Oct. 1940, 15 pp.) with just that. Depending on the particular application, either creep or rupture after long periods of time may be the criterion of successful operation, so both properties should be known if high temperature behavior is to be predicted with any certainty.

A combined plot of creep and rupture test results presented is found to be useful in correlating the creep and rupture properties, and affords a convincing means of arriving at safe working stresses for design purposes. With some materials [as noted above] there is good reason to believe that the amount of elongation accompanying long-time fracture will be very small indeed. Usually, these materials possess high creep strengths and fail by a process of intergranular cracking.

For materials of this type, long-time factors of safety against failure may be almost lacking if design stresses are based on the value that will produce 1% of creep in 100,000 hrs. On the same basis, materials that do not fail by intergranular cracking in tests of long duration usually show much larger factors of safety against failure.

In a further correlation of creep and rupture tests, A. W. WHEELER ("A High-Temperature Bolting Material," *Preprint, Am. Soc. Mech. Engrs.*, Dec. 1940, 8 pp.), using 4-in. diam. specimens of a 0.45% C, 1 Cr, 0.35 Mo, 0.26 V, 0.6 Mn, 0.3 Si steel, noted that the ratio between creep strength and rupture strength is greater in the case of normalized material than for oil-quenched. It is believed that changes in heat treatment, differences in melting practice, and even slight changes in some alloying elements can greatly affect the ratio of creep strength to rupture strength

X (3a)

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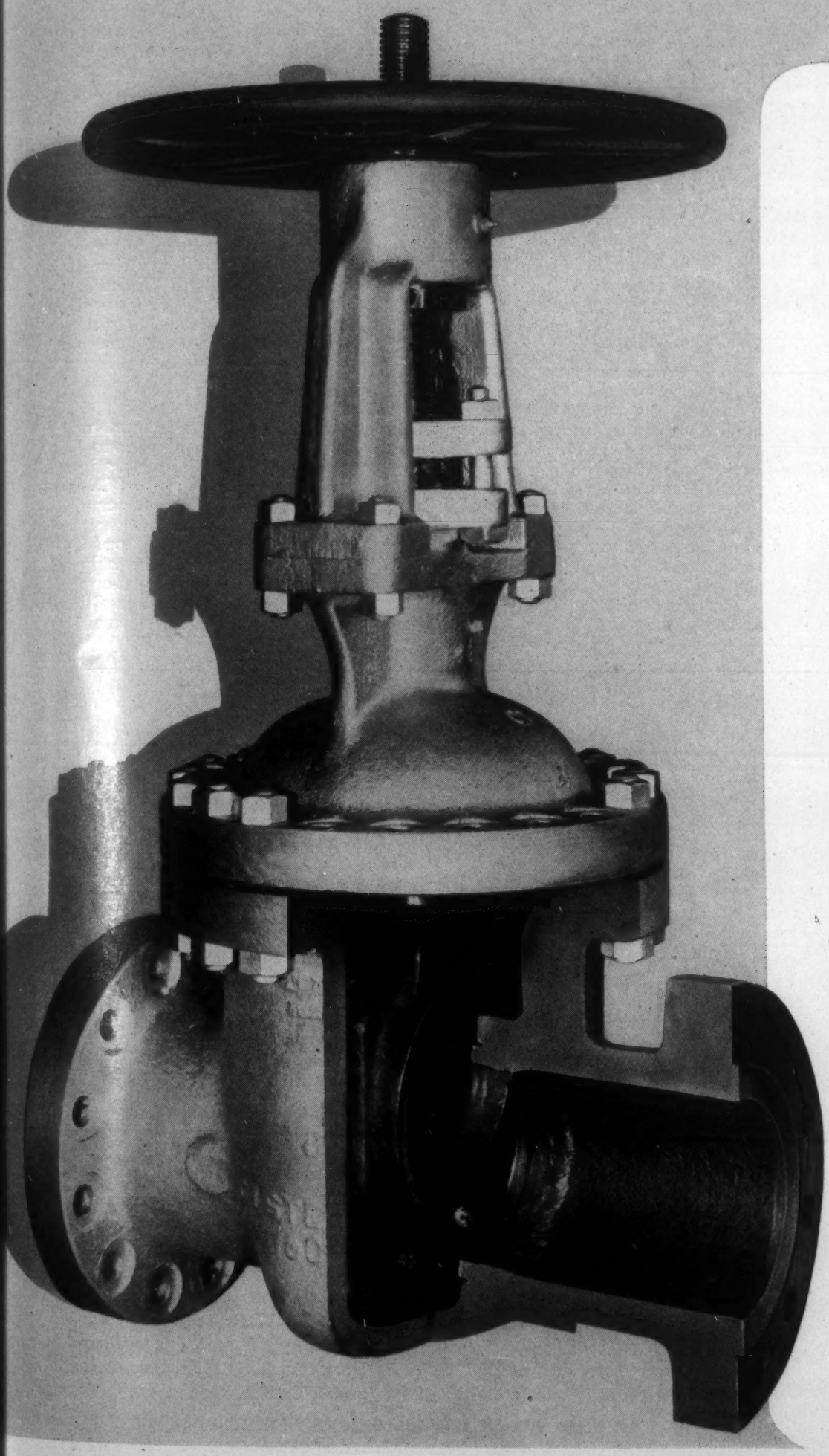

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Coatings and Fatigue

A Correction

In the composite digest on "Protective Coatings Against Corrosion Fatigue of Steel" published in our August 1940 issue, p. 208, a table was presented containing data on the "ratio of endurance limit in water to endurance limit in air" of steels with various protective coatings. These values were calculated by our staff from figures given in the original papers, and we now learn that two of the values attributed to Kenyon were erroneously worked out.

The value of this ratio for "Bead Wire, no coating" should be 0.243 rather than the published 0.522, and for "Bead Wire, copper-zinc plated" (the bottom-most line) 0.507 rather than 0.426. The first error is fundamentally misleading, since it gives the impression that the untreated wire had the *highest* ratio, whereas actually it had the *lowest* of Kenyon's materials in the Table. —F. P. P. (3a)

3b. Non-Ferrous

Corrosion of Aluminum Alloys

A Composite

German experience with aluminum alloys has been greater, in proportion, than that of other countries. The reasons for this are interesting. German autarchy has found the light, strong aluminum alloys well suited to many industrial needs that ordinarily might involve metals not produced in the Reich (Germany has no appreciable bauxite deposits, but she does have vast facilities for processing bauxite obtained from countries dominated by or friendly to her); also, the German aircraft "industry," it now appears, must have handled tremendous amounts of aluminum and its alloys during the last six years.

German advocacy, therefore, of specific practice with respect to designing for certain aluminum alloys must be viewed with a mingling of respect for a probably authoritative viewpoint and of critical recognition that the conditions may be special and non-generalizable or that a bit of wishful thinking may even be present.

In the group of articles summarized herewith, the corrosion resistance of aluminum alloys for food processing is discussed, methods of improving the resistance to stress-corrosion of aluminum alloy products suggested, and the utility of zinc-bearing aluminum-magnesium alloys (which entail no metal-importation, in contrast to the aluminum-copper alloys) favorably examined.

Aluminum in Food Processing

The beer industry was once practically a staple industry in Germany, although the government is reported to be currently attempting to revise downward the national beer consumption. Anyway, G. REIF ("Versuche über das Verhalten von Aluminium und Aluminiumlegierungen gegen Bier," *Aluminium,* Vol. 22, Apr. 1940, pp. 190-191) reports on the relative corrosion resistance of aluminum and certain aluminum alloys against beer. Beer produces on aluminum a smooth precipitated scale, which under suitable conditions protects the metal against further corrosion.

Chemical treatment and anodic oxidation of the metal were studied for their effects on resistance. It was found that aluminum purity or alloy composition was less important than the type of surface treatment (as with milk). The corrosion by beer was least with sheets anodically oxidized in oxalic acid.

Food-processing equipment must be regularly sterilized, and the disinfectants used often introduce a corrosion problem for users of aluminum equipment. H. WOLF ("Desinfektionsmittel für Aluminium-Behälter und Aluminium-Geräte," *Ibid.,* May 1940, pp. 270-272) has studied the effect on aluminum of several proprietary and non-proprietary German disinfectants. "Neomoscan," a dilute (1:100) alkaline solution of sodium silicate and sodium hypochlorite used for dairy equipment, was without effect on aluminum. "Microformin," a neutral, 1% "stabilized" formaldehyde attacked the metal only insignificantly. A compound that seemed to have special merit was "P3-Sterile," a chlorine containing phosphate-silicate mixture used in concentrations of less than 1%.

Other Corroding Conditions

The general corrosion resistance, under certain common conditions, of various high strength aluminum alloys is investigated by P. BRENNER & F. PLATTNER ("Korrosionsverhalten von Aluminiumlegierungen höherer Festigkeit unter natürlichen und künstlichen Bedingungen," *Ibid.,* pp. 231-247). Of all the materials investigated (aluminum-magnesium, aluminum-copper-magnesium, aluminum-magnesium-silicon, aluminum-manganese alloys) in these 3½-

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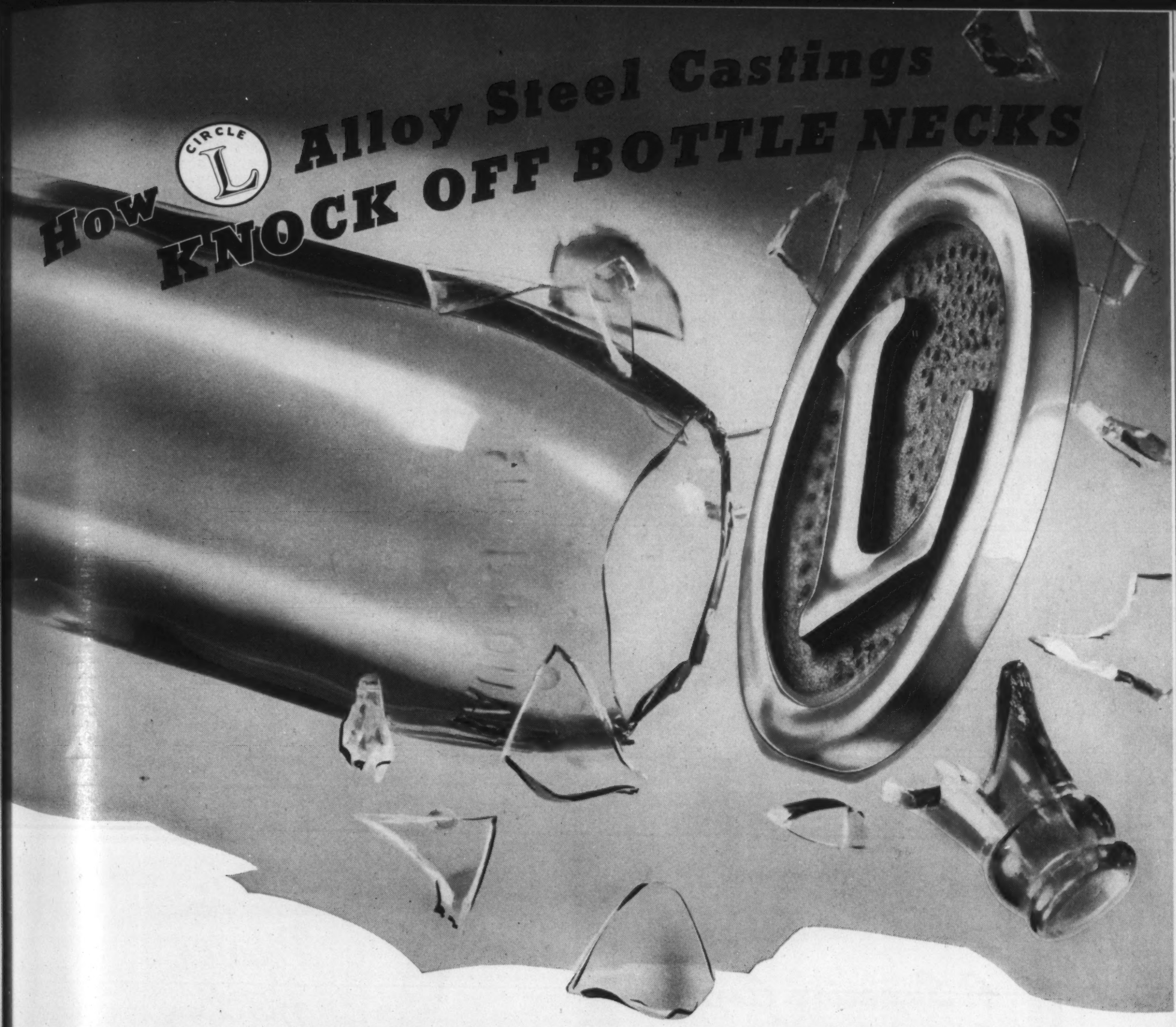

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yr. tests, the aluminum-clad aluminum-copper-magnesium alloys showed the most resistance, and the corrosion resistance was only slightly impaired if some of the copper of the core material diffused through to the surface of the clad layer.

Aluminum-copper-magnesium alloys clad with aluminum - magnesium - silicon alloy were corrosion-resistant if aged at room temperatures, but not if precipitation-hardened at high temperatures. Variations in chemical composition among the aluminum-copper-magnesium alloys had little effect on corrosion resistance, but the straight aluminum-magnesium alloys had a tendency toward intercrystalline corrosion.

Elsewhere BRENNER ("Ueber das Korrosionsverhalten von Leichtmetallschweissungen," *Autogene Metallbearbeit.*, Vol. 33, July 15, 1940, pp. 169-175) reports on the corrosion behavior of light metal welds in several types of aluminum alloys. Welded or unwelded, the highest corrosion resistance (in 3% NaCl + 0.1% H_2O) was manifested by pure aluminum, aluminum-manganese alloy and aluminum-magnesium-manganese alloy, all of which survived 2-yrs. exposure without noticeable deterioration of mechanical properties.

Aluminum-magnesium alloy welds are not so resistant as the unwelded alloy, which is on a par with the materials mentioned above. The corrosion resistance of aluminum-copper-magnesium alloy, initially lower than that of the copper-free materials, is still further lowered by welding. Welds in aluminum-clad alloys were more corrosion resistant than those in aluminum-magnesium-silicon-clad materials.

A good inhibitor of attack on aluminum by dilute alkaline solutions, according to H. WOLF & H. TUXHORN ("Silicofluorid als inhibitorisch wirksamer Zusatz zu Aluminium angreifenden Lösungen," *Aluminium*, Vol. 22, Apr. 1940, pp. 186-187), is 0.05 to 0.1% (at room temperature) of sodium silicofluoride. In boiling solutions, about 0.2% should be used.

Intercrystalline and Stress Corrosion

Aluminum-magnesium alloys quenched from 850° F. and aged between 200° and 475° F. are subject to intercrystalline corrosion through the precipitation of Al_3Mg_2 at the grain boundaries. The effect of small additions (0.5% each) to a 7%-Mg aluminum alloy on this type of corrosion was investigated by WILLI MULFINGER ("Ueber den Einfluss geringer Zusätze metallischer Elemente auf die interkristalline Korrosion von Aluminium-Magnesium-Legierungen," *Z. Metallkunde*, Vol. 32, Sept. 1940, pp. 311-313). The added elements included lithium, beryllium, calcium, titanium, zirconium, cerium, thorium, vanadium, columbium, tantalum, chromium, molybdenum, tungsten, manganese, iron, cobalt, nickel, copper, silver, zinc, silicon, tin and antimony.

Only the alloys containing silicon, titanium and zirconium were unattacked (by 1% HCl, 3% NaCl solution) at the grain boundaries after aging at 400° F. Tungsten, zinc and tin additions appeared to accelerate the attack, but a zinc addition of 2% strongly improved the resistance to intercrystalline corrosion of alloys aged at 400° F.

Stress corrosion—corrosion engendered or accelerated by stressing — is another problem, and its general aspects with respect to aluminum-magnesium alloys are discussed by L. GRAF ("Zum Problem der Spannungskorrosion," *Luftwissen*, Vol. 7, No. 5, 1940, pp. 160-169). In such alloys stress corrosion starts with the first sign of *plastic* deformation. There is a "minimum stress" in any instance below which no stress corrosion takes place, and in the case of cast alloys, this limit is higher than the yield point.

Zinc Additions and Stress Corrosion

According to G. SIEBEL & H. VOSSKUHLER ("Einfluss von Zusätzen, insbesondere von Zink, auf das Korrosionsverhalten von Aluminium - Magnesium - Legierungen," *Z. Metallkunde*, Vol. 32, Sept. 1940, pp. 298-302), zinc is the most effective addition agent in reducing the stress corrosion of aluminum-magnesium alloys with over 7% Mg. Thus, an alloy with 8% Mg, 1% Zn, 0.3% Mn and 0.12% Cr shows under a variety of stress-corrosion-testing conditions much better resistance than an alloy containing 8.5% Mg and 0.3% Mn (which has about the same mechanical properties).

The well-known susceptibility of higher-zinc-content alloys can be offset by additions of chromium, for example. The addition of 0.2% Cr to a 6% Mg, 4 Zn, 0.3 Mn alloy gives an alloy of high strength and ductility when age-hardened, together with considerable stability against stress corrosion.

Taking the aluminum-zinc-magnesium alloys as a ternary system, G. WASSERMAN ("Der Einfluss von Zusammensetzung und Wärmebehandlung auf die Spannungskorrosion aushärtbarer Aluminium-Zink-Magnesium-Legierungen," *Ibid.*, pp. 295-298), studied the effects of composition and heat

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treatment on their susceptibility to stress-corrosion by 3% NaCl + 1% H_2O_2 solution. An alloy of 4% Zn, 3 Mg was vastly superior to an equally strong alloy with 8% Zn, 0.8 Mg.

Manganese is helpful in counteracting stress-corrosion tendencies as well as improving the properties generally. An alloy containing 6% Zn, 1.4 Mg, 1 Mn, aged to 60,000 lbs./in.^{2} (17% elongation) by quenching from 750° F. failed by stress-corrosion in 72 hrs.; however, no failure occurred after 2200 hrs. when the alloy was air-cooled from 750° F. and aged to 59,000 lbs./in.^{2}

This author's contention that stress-corrosion can be licked by employing suitable compositions and heat treatment is strongly supported by data of M. HANSEN, A. MÜHLENBRUCH & H. J. SEEMANN ("Ueber das Spannungskorrosionsverhalten von Aluminium - Zink - Magnesium - Legierungen," *Metallwirtschaft*, Vol. 19, No. 26, 1940, pp. 535-538). Aluminum-zinc-magnesium alloys, in which the sum of magnesium plus zinc does not exceed 6%, are not affected by the temperature of solution anneal (between 715° and 930° F.), by the quenching treatment (*i.e.* either air-cooling or water-quenching) and by aging treatments between 170° and 480° F. In other words, these alloys are absolutely stress-corrosion proof.

With magnesium plus zinc contents exceeding 6%, air-cooling is indispensable to improve the resistance against stress-corrosion. (*See the digest "Aluminum-Zinc-Magnesium Alloys" just following this one*). Alloys aged at room temperatures are not affected in regard to stress-corrosion by additional aging at higher temperatures, in contradistinction to straight aluminum-magnesium alloys with higher magnesium contents. Cold reduction of 10% does not notably affect the corrosion stability of air-cooled alloys.

The interrelation between grain size and stress corrosion of wrought aluminum-magnesium alloys is investigated by F. BOLLENRATH & W. BUNGARDT ("Korngrösse und Spannungskorrosionsverhalten von Aluminium-Magnesium-Knetlegierungen," *Z. Metallkunde*, Vol. 32, Sept. 1940, pp. 303-305), using alloys with 7% Mg and 9% Mg and with 8% Mg + 1 Zn in 3% NaCl solution. Coarse-grained material was superior to the same material in the fine-grained state. Air-cooling improves stability [*this agrees with the findings of Hansen, Mühlenbruch & Seemann, above*].

Addition of 1% Zn entails an improvement in resistance to stress corrosion in both the air-cooled state and after "heterogenizing." The last heat treatment is the determining factor, and can offset faulty thermal pre-treatment. The favorable effect of zinc is attributed to the fact that the critical temperature range for stress-corrosion is shifted to temperatures 75° F. higher—or to well over 200° F. X (3b)

Aluminum-Zinc-Magnesium Alloys

INVESTIGATIONS OF ALUMINUM-ZINC-MAGNESIUM ALLOYS. MECHANICAL PROPERTIES IN COLD PRECIPITATION-HARDENED CONDITION ("Untersuchungen an Al-Zn-Mg-Knetlegierungen. Festigkeitseigenschaften im kaltausgehärteten Zustand") M. HANSEN, A. MÜHLENBRUCH & H. J. SEEMANN. *Aluminium*, Vol. 22, Sept. 1940, pp. 442-458. Research.

Although aluminum-zinc-magnesium alloys can be age-hardened at both low and moderately high temperatures to develop considerable mechanical strength they have not been extensively used, owing to their tendency to stress corrosion. This tendency, however, can be eliminated by suitable special heat treatment. Thirty-three alloys were investigated, with compositions of 0.97-6.2% Mg, 2.25-6.95% Zn, 0.25-1.02% Mn, 0.17-0.34% Fe, and 0.11-0.84% Si.

The mechanical properties of cold-precipitation - hardened aluminum - zinc - magnesium alloys with up to 7% Zn and up to 6% Mg are practically independent of the solution temperature (investigated range: 715°-970° F.) Time periods at solution temperature of 20 min. (in salt baths) are quite sufficient. In some cold-aged alloys the optimum of properties is not reached even after 90 days at cold storage. In certain cases, air-cooling after solution annealing reduces the strength, but this can be counteracted by a cold-deformation, *e.g.* of 5%.

Alloys of about 55,000 lbs./in.^{2} tensile strength, 35,000 lbs./in.^{2} elastic limit and 15% elongation that are resistant to stress corrosion can be produced by 2 principal compositions: (1) an alloy with about 2% Mg and 6% Zn in the air-cooled, cold-precipitation-hardened state; (2) another with about 2% Mg and 4% Zn treated by quenching in water from the solution temperature and subsequently precipitation-hardening at 175-210° F. The optimum manganese content is about 0.5-0.8%, and silicon should not exceed 0.5%. Ha (3b)

AT THE PRESENT TIME

A sellers' market exists for some of the non-ferrous metals. A sellers' market is not always an ideal one even from the point of view of the seller. When the demand exceeds the supply, customers are not properly taken care of and are not at all satisfied; the seller is equally unhappy. A situation such as the present one may break up business relations of long standing, and the sellers realize this.

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Inclusion Ratings for Steel

"Non-Metallic Inclusions in Steel. Quantitative Evaluation.—Part I." W. H. Hatfield & G. W. Giles. *Iron & Steel Inst.*, Adv. Copy, Nov. 1940, 20 pp. Research.

Several inclusion charts now in use for grading of steels are discussed. Eight different steels were graded at magnifications of 27.5, 82, 132, 250, 520, 1200 and 2000.

The magnification of 27.5 was too low for many of the inclusions to be visible. For the other magnifications the inclusion rating tended to decrease as the magnification increased. It is concluded from this that the comparison charts now extant do not have the quantitative value heretofore attributed to them.

While the conditions of polishing materially influence the inclusion count as determined by the methods at present in vogue, a light etch tends to establish what appears to be a more reliable basis for comparison. Until solutions have been found for the present disabilities, the present methods of quantitative estimation of the degree to which steels are contaminated by non-metallic inclusions are impracticable.

JLG (4)

Spectrography of Aluminum Alloys

A Composite

A series of recent articles in the German magazine *Aluminium* has covered certain aspects of the spectrographic analysis of aluminum alloys, particularly the form in which the material should be for analysis.

As the amount of zinc in aluminum alloys can have a critical effect on corrosion resistance, its determination by rapid methods is desirable. G. Balz ("Die spektrographische Bestimmung kleiner Gehalte von Zink in Aluminium und seinen Legierungen," *Aluminium,* Vol. 22, July 1940, pp. 341-343), states that the spark spectrum method is reliable only with zinc contents over 1% because the intensity of the zinc lines in the spark spectrum is too weak, and describes a more suitable spectrographic method.

In the new method, a discontinuous electric arc (2 mm.) with 3 mm. diam. electrodes of the material to be analyzed is photographed with an exposure of 1-3 min., and the photograph evaluated photometrically. Zinc contents above 0.07% can be detected, using the line Zn 3345.

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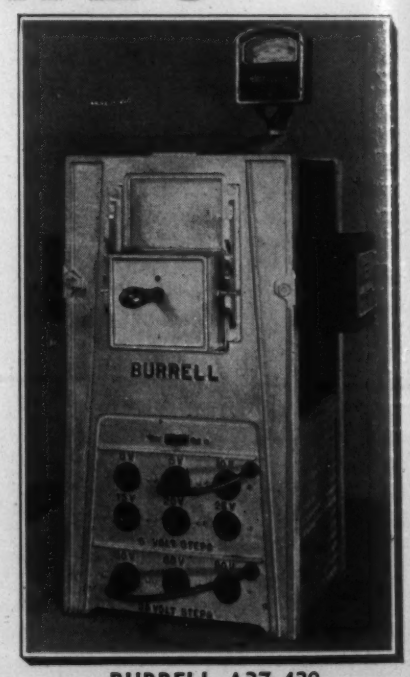

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uniformity of composition of both the calibration electrode and the specimen electrode over their entire length and section, says H. MORITZ ("Herstellung und Prüfung einwandfreier Eich- (Standard-) Elekroden für die Leichtmetallspektralanalyse," *Ibid.*, Sept. 1940, pp. 421-435), describing methods of preparing and testing satisfactory calibration electrodes for aluminum analysis. Electrodes may be either pressed-and-drawn, or die cast.

In another article BALZ advocates the use of a logarithmic rather than a linear galvanometer scale for the photometric observation of density in quantitative work ("Die Messung der Schwärzung von Spektrallinien mit Hilfe einer logarithmischen Galvanometerskala," *Ibid.*, July 1940, pp. 343-344), since the density of the photographic film is related logarithmically to the photocell current.

Also, BALZ ("Ein automatisches Zeitschaltgerät für Spektralaufnahmen," *Ibid.*, pp. 344-345) describes an automatic timing device for adjusting exposure time, exposure cycles or whole operating schedules for either spark or arc spectrography. Ha (4)

Photronic Radiation Pyrometer

"A HIGH-SENSITIVITY RADIATION PYROMETER." N. E. DOBBINS, K. W. GEE & W. J. REES. *Foundry Trade J.*, Vol. 63, Oct. 10, 1940, pp. 235, 238. Descriptive. Reprinted from the *Trans. British Ceramic Soc.*

For many super-high-temperature purposes optical pyrometers of the polarizing and disappearing filament type, with sensitivities of about 35° F. per scale division at 3500° F., are not sufficiently precise. A radiation pyrometer of high sensitivity was developed, which gives a direct reading of temperature through a lens, mirror, ground-glass-screen and photocell system.

The photoelectric cell, its collecting lens and the screen are mounted at one end of a brass tube. The other end of this tube is closed by a hardwood flange bored to take the draw-tube which carries another lens. An elliptical hole is cut in the screen of such dimensions that the light forming the center part of the image of the test-piece is allowed to pass through the screen and strike the photoelectric cell.

After preliminary adjustment for object distance has been made, the draw-tube is locked in position, so that the area of the hole in the screen retains a constant relation to the area of surface of a hot body focussed on this screen. Now, so long as the image of the hot body is brought to a focus on the screen, the light reaching the photoelectric cell bears a constant relation to the light emitted by a definite area of the surface of the hot body.

In other words, whenever the instrument is brought into its working position in front of a hot body at given temperature, the same amount of light will always fall on the cell, and hence the cell itself will always cause the same current to flow in its galvanometer circuit. This pyrometer, in common with others, will not read through fumes.

A pyrometer of this type should be especially valuable in various temperature-controlled processes. The apparatus can be adjusted to give its maximum sensitivity at any working temperature, and under operating conditions a variation in temperature of ±2° F. could be recorded. It would be possible to arrange a mirror galvanometer system that would throw a spot of light onto a second cell whenever the temperature deviated from that required by ±2° F. and this second cell could be set to work a relay and give either visual or audible indication of the deviation. AIK (4)

Testing Lead Cable Sheathing

"BURSTING TESTS AND TENSION TESTS FOR LEAD CABLE SHEATHING." H. F. MOORE, C. W. DOLLINS & W. J. CRAIG (Univ. Illinois) *Preprint, Am. Soc. Testing Materials,* June 1940, 6 pp. Descriptive.

In cooperation with the Philadelphia Electric Co., comparative tests to fracture under long-time steady load were made (1) by subjecting full sections of lead cable sheathing to internal oil pressure, and (2) by testing tension test specimens cut with the axis in a circumferential direction from pieces of the same sheathing.

Four sets of tests were made, and good agreement was found between the nominal stress developed in the bursting test and the tensile strength developed in the tension tests. There was also good agreement between the increase of diameter in the bursting tests and the elongation of the tension test specimens.

It was concluded that the prediction of tensile strength and static ductility under long-continued steady load could be judged as reliably from tension tests of specimens cut from sheathing as from bursting tests of short pieces of sheathing. Similar tests on sheathing made from other grades of lead and of sheathing made from some of the harder alloys of lead seem desirable to determine whether similar agreement between bursting tests and tension tests would be found for these metals. VVK (4)

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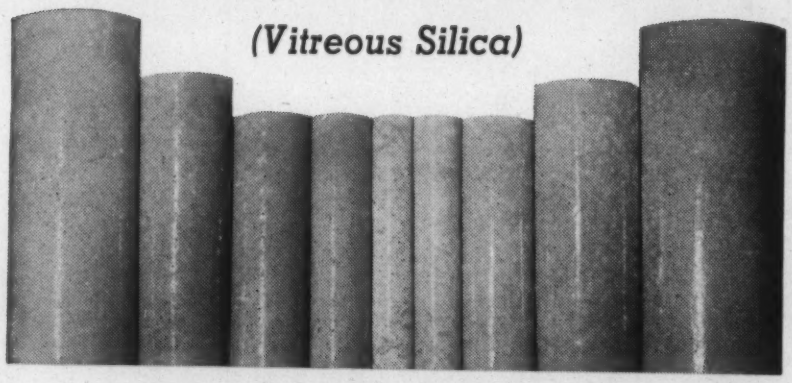

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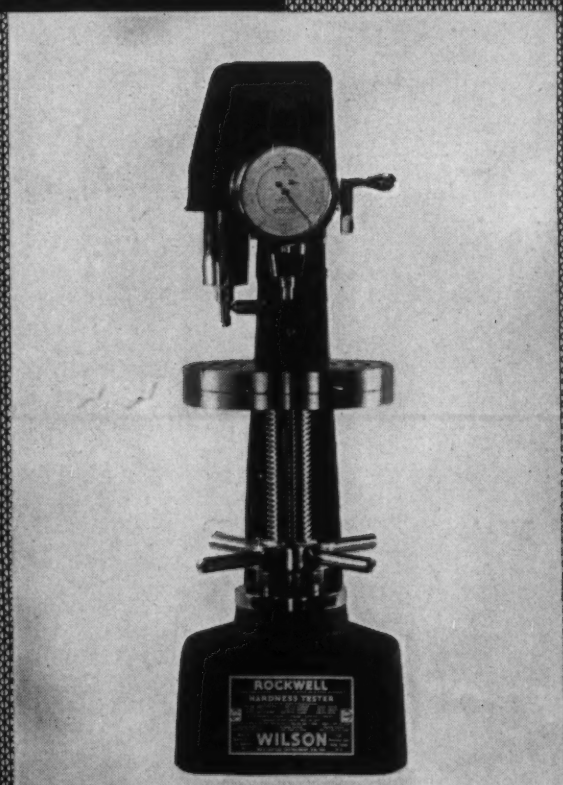

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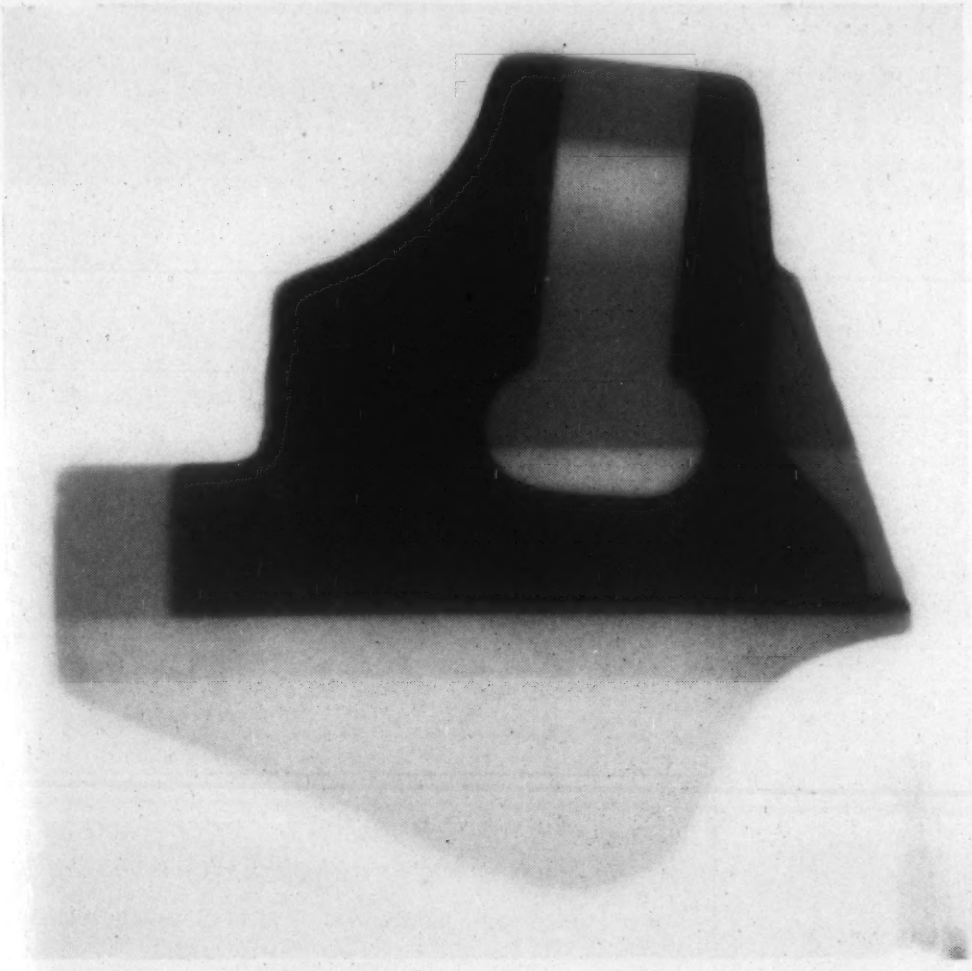

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Hardenability of Tool Steels

"Hardenability Testing Tool Steels by Oil Quenching Small Cones." E. K. Spring & J. K. Desmond (Henry Disston & Sons, Inc.) *Steel*, Vol. 107, Oct. 28, 1940, pp. 58, 60-62. Description of new method.

Most methods proposed for the determination of hardenability are not entirely satisfactory for tool steels. What the authors required was an oil-quench test that could be transposed into water-quenching terms, if desired.

The method developed uses specimens 8 in. long, 6 in. of which are tapered from 0.625-in. diam. to 0.200-in. diam. The cone is an easy specimen to prepare and handle, as it machines conveniently, hardens from a lead pot, and can be ground quickly. The total time for completion of a cone test is somewhat longer than for a 1-in. square test.

The cone test compares favorably from time and cost viewpoints with the other proposed methods, and results are more accurate, as the quantities measured are of larger dimensions; Rockwell hardness testers and micrometers give the precise information needed; a machined surface free from decarburization before and after hardening is used; and the oil-quench cone displays the hardenability of the steel in several ways.

As the included angle of the cone is 6°, accurate Rockwell hardness readings can be taken on the surface after hardening, as well as along the axis. Water-quenched cones, unless of extreme size, harden over their entire surface, while an oil-quenched cone has a diameter at which it will not harden. The surface hardness does not drop continuously; there is an area on the outside that contains both hard and soft spots, but after this area is passed, the hardness does drop continuously.

On an etched sectioned cone, the decrease in hardness takes on the appearance of a parabola, with its vertex located at different points along the axis for steels of different hardenability; the vertex also moves as the quenching temperature is changed. After the desired measurements have been taken, the cone can be easily broken for a Shepherd grain size examination. Steels can be classified as to hardening characteristics to much finer shades than by other methods. MS (4)

Weldability Tests for Steels

"A Comparison of Tests for Weldability of Twenty Low-Carbon Steels." C. E. Jackson & G. G. Luther (Naval Research Lab.) *Welding J., N. Y.*, Vol. 19, Oct. 1940, pp. 351s-364s. Research report.

A survey study was made on a series of 20 carbon steels ranging from 0.10% to 0.54% C, both rimmed and silicon-killed. The various tests that have been proposed for determining the weldability were surveyed and the following 8 were applied to the steels:

(1) *Single Vee-groove weld test,* in which Vickers hardness indents spaced at 0.05 in. intervals across the weld serve as gage marks for determining ductility across the weld in a bend test.

(2) *Tee bend test,* in which a section of plate is welded normal to another plate by means of 2 fillet welds to form a tee section. This section is bent, in a special jig, to failure.

(3) *Vee-notched slow-bend test,* where a notch is cut in a bead weld, the notch being located at the transition from weld metal to the plate metal. A 0.20 in. thick sample is bent around a 0.40 in. diam. pin until the first appearance of a crack at the root of the notch is noted.

(4) *Vee-notched impact test,* in which a standard V-notched Charpy bar is prepared by machining a notch with the apex tangent to the fusion line of a bead weld. The sensitivity of the steel to welding is evaluated by a comparison of plate and bead weld impact specimens.

(5) *Longitudinal bead weld slow-bend test,* in which a bead weld after removing excess weld metal is bent in a simple jig and elongation on tension face, containing the weld bead, is used as index of ductility and weldability.

(6) *Maximum hardness* determined by a hardness traverse across the weld.

(7) *Weld quench test,* which is a comparison of impact value of half-size Charpy keyhole notched bars of the base metal and the base metal heat-treated to simulate large-grained area of base metal next to weld.

(8) *Cold rolling,* which consists of cold rolling a uniformly surface ground section of the weld to failure.

The data for all these tests are tabulated and plotted by the authors, and test conditions described in detail. Automatic arc welding was employed throughout the tests, using heavily-coated reversed-polarity mild steel electrodes in 3/16 and 1/8 in. diam.; some gas welds were also made and tested.

It is concluded that the effects of a standard welding technique or a range of welding techniques on a steel or series of steels may be completely determined by tests of (a) chemical analysis; (b) mechanical properties (tensile and impact); (c) actual weld joint such as the single Vee-groove weld; (d) T-bend, (e) Vee-notched slow bend, (f) structure and hardness. WB (4)

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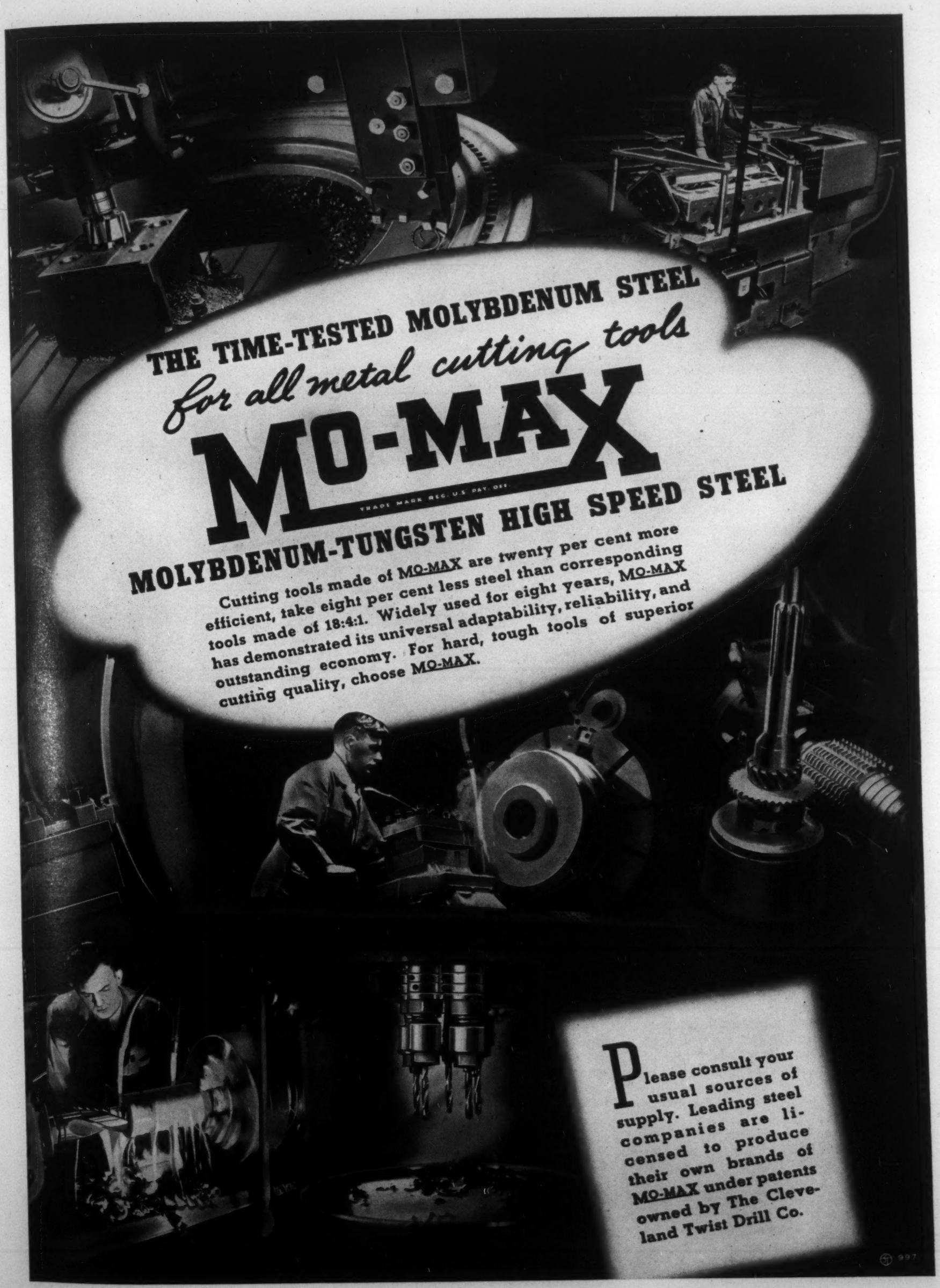
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Steel Castings

STEEL CASTINGS HANDBOOK. *Published by Steel Founders' Society of America, Cleveland, 1941. Cloth, 6 x 9 in., 503 pages. Price $2.00.*

The activities of the technical organizations in the metallurgical engineering industries devoted to the preparation and steady revision of handbooks are among their most useful functions. One goes to the "Metals Handbook," to those on Cast Iron and Alloy Cast Iron, to the Welding Handbook, etc. with assurance that reliable information, checked by many experts, will be found. This "Steel Castings Handbook" is no exception in this respect. It *is* an exception in the profuseness of illustration, a feature that adds to readability.

The handbook is written more for the present and potential user of steel castings than for the foundrymen who produce them. This doesn't mean that it is not replete with information for the latter, merely that the emphasis is put on what the user ought to know. Sound discussion of the range of properties on the basis of probability data, and of casting design to produce greatest soundness and avoid shrinkage and hot-tear difficulties, is so brought in that the user should grasp it, and even feel that he is picking up information that the author is presenting to the foundrymen. This indirect method of accomplishing a desired end is very effectively used.

However, this point of view leads to the omission of one matter the foundryman might properly have expected would be discussed—the problem of avoiding porosity without running into low ductility. This is evidently considered to be a matter to be discussed only in the bosom of the foundry family, without bringing to the notice of the user the idea that porosity or low ductility might exist in steel castings made by foundries not up on their control.

The topics covered are: History, definitions, manufacture, properties, heat treatment, variables affecting properties, carbon steels, low-alloy steels, heat- and corrosion-resistant steels, manganese steel, engineering properties, specifications, design, pattern equipment, recommendations to purchasers, commercial applications, and the appended tables, etc. expected in a handbook.—H. W. GILLETT.

"Practical" Metallurgy

PRACTICAL METALLURGY. *By G. Sachs & K. R. Van Horn. Published by American Society for Metals, Cleveland, 1940. Cloth, 6¼ x 9¼ in., 567 pages. Price $5.00.*

Carpenter and Robertson's book, "Metals," costs $35.00. Hansen's "Zweistofflegierungen" costs $25.00. This volume comes pretty close to giving the meat of the contents of both these books. The style is in sharp contrast to the rambling and contemplative style of Carpenter and Robertson, for it is highly compressed. Indeed, it is so compressed that the reader continually finds himself panting in the effort to keep up, when trying to read it continuously. It will seldom be read continuously, for it will be most used for reference, which use is much facilitated by the comprehensive index.

The condensed style is a difficult one to use and still avoid misleading statements due to not having enough space to qualify the generalizations sufficiently. Yet there are scarcely half a dozen paragraphs that are open to ambiguous or erroneous interpretation from this cause. And the copious references to pertinent literature, nearly 1500 of them, make it possible for the reader who has complete library facilities to go more deeply into any topic. For the reader with very limited library facilities, the book may be over-condensed, but between condensation and verbosity, the former is preferable.

The combination of Sachs, with all the German literature at his tongue's end, and Van Horn, with his grasp of American information and plant practice and problems, is a peculiarly happy one. Few books have been written by authors with comparable command of the world literature of their topic. Sometimes the reader suspects that the authors may be giving a little more credence to what some previous author has concluded than is really justified, but if the reader is a bit incredulous, he can chase down the references and draw his own conclusions.

The book is especially strong in discussion of cold forming, internal stress, and aluminum and magnesium alloys, matters in which the authors have special experience and background. The emphasis is on physical metallurgy. Process metallurgy, when incidentally dealt with, is handled in less decisive fashion, the discussion of melting practice, for example, not being up to the standard of the bulk of the book.

Whether the title "Practical" is entirely justified depends on the reader's point of view. A strong effort has been made to correlate theoretical generalizations with the problems of practice, and the effort has met with considerable success. Yet many metallurgical engineers and "practical" metallurgists will find the book pretty strong meat unless they have had a soup course of several more elementary texts.

One thing the book does do is to completely and properly ignore any dividing line between ferrous and non-ferrous metallurgy. It is quite up to date. A good proportion of the references are to 1940 publications. Established trade names, both American and foreign, that mean something as to composition and properties, are not avoided, and appear in the index as well as the text.

The chapter headings cover constitution, grain structure, crystal structure, phase changes in the solid, deformation and recrystallization, residual stresses, furnaces, etc.; production, properties and special matters relating to castings; ingots, mechanical working of all types, heating and heat treatment of steels and non-ferrous metals. This all refers chiefly to the common industrial metals and alloys. The appendix of binary constitutional diagrams includes many less common systems.

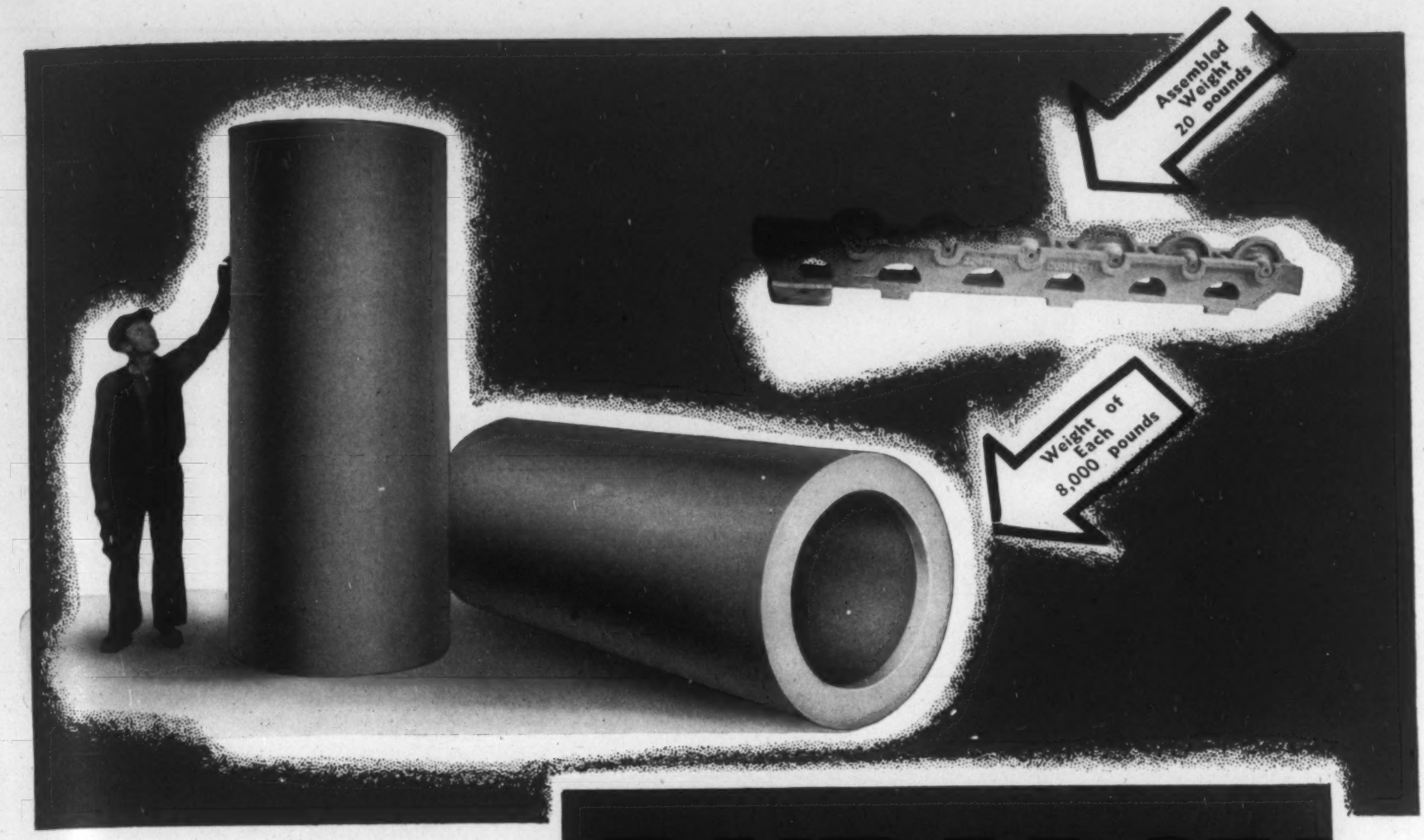
Of course, many important matters can have but the barest mention in a book of this wide scope and relatively small size. One complete omission is that of the whole group of mild-alloy-steels, from Cor-Ten to Yoloy. But, on the whole, there is more adequate coverage than one would normally expect in 567 pages.—H. W. GILLETT.

Other New Books

ARC WELDING—MANUAL AND OPERATOR'S TRAINING COURSE. *Published by The Hobart Brothers Co., Troy, Ohio, 1940. Paper, 5½ x 8 in., 98 pages. Price 50c.* This is a section taken from a 340 page book, "Arc Welding and How to Use It." The present section is devoted to the very practical fundamentals of the art.

LESSONS IN ARC WELDING. *Published by Lincoln Electric Co., Cleveland, Ohio, 1940. Cloth, 5¾ x 8¼ in., 136 pages. Price 50c.* Textbook for the lessons given in the Lincoln Arc Welding School. Refers only to use of Lincoln equipment. Simply written, for the practical welder.

ALLOY HANDBOOK—SUPPLEMENT (Handbuch aller Legierungen—Nachtrag) *By Ernst Jänecke. Published by Robert Kiepert Verlag, Berlin-Charlottenburg, 1940. Cardboard, 7 x 9½ in., 123 pages. Price 16 RM.* Incorporates references to and brief comment on the literature of alloys from 1937, the date of publication of the handbook, to 1940. The index covers both the handbook and the supplement.



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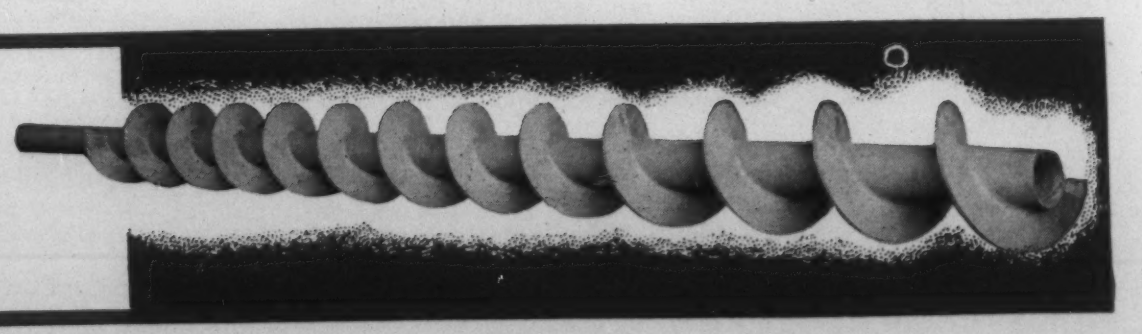

One-piece screw conveyor indicative of the class of work we do on centrifugal castings.

trends

By Edwin F. Cone, Editor

Stainless Steel

The use of stainless steel in the American transportation industry is expanding rapidly. This is pointed to as due to two facts: Its very great inherent strength and the rapid advance in the knowledge of how to handle it. "Transportation will find that this material permits them to liquidate rapidly its added cost. As a result, fleets of stainless steel commercial trailers are growing rapidly in all sections of the country and in many types of industries and vocations. The combination of stainless steel plus shot-welding may be readily held as one of the biggest strides in transportation development during the history of this new and versatile industry."

Tin and Terne Plate

Capacity of the tin and terne plate industry increased 5.1 per cent between 1937 and 1939, but output fell off 5.6 per cent, according to a preliminary report of the Census of Manufactures for 1939. A comparison of capacity with output shows that, in the event of necessity, production could be doubled if existing facilities were used on a 24-hr. a day, year-round basis and if sufficient raw materials were available. Thus potential output is 10,187,567,560 lbs. against an actual output last year of 5,711,326,129 lbs.

Plastics in German Aircraft

Plastics are being used in German aircraft for small parts that take no great strain, such as electrical appliances and transparent plastics in the upper portion of cockpits—according to the *Foreign Commerce Weekly*. It is not believed that plastic wings or fuselages are being made.

New Alloys

"Ten thousand (10,000) new metal alloys and 250,000 new chemical compounds have been discovered in the last few years." Assuming this statement regarding alloys to be true, the trend continues—due to the results of research and the growing availability of rare metals.

Steel Sales Offices

Reflecting the nation-wide distribution of consumers of iron and steel 36 of the 48 states contain at least one steel company sales office, says the American Iron and Steel Institute. No less than 165 cities contain either a branch sales office of some steel company or the office of a sales agent for one of the companies in the industry. Outside the continental United States, companies in the steel industry maintain about 40 sales offices.

Steel Industry's Supply of Labor

Because of measures applied by the steel industry over a period of years such as apprentice programs, job-training for specific duties, work-sharing during depression periods and high wage scales, adequate reservoirs of labor have been built up so that, says the American Iron and Steel Institute, no serious shortage of labor exists, nor is any likely to develop soon.

German Steel Capacity

As a result of the annexation and military occupancy of certain European countries, Germany's steel ingot capacity is estimated as more than double what it was before the war. On the basis of theoretical capacity and taking into consideration the expansion in Germany's own industry, steel ingot capacity is probably close to 46,000,000 metric tons. By comparison, Britain's capacity is about 15,000,000 and that of the United States over 79,000,000 gross tons.

Ferroalloys

In 1939 there were 13 blast furnaces and 23 electric furnaces producing ferroalloys of all kinds—in 1937, says the Census of Manufactures for 1939, there were 11 and 22 furnaces respectively. Twelve furnaces in 1939 were making ferromanganese and spiegeleisen—9 in 1937; 13 each year were producing ferrosilicon. In 1939 there were 19 furnaces, against 21 in 1937, producing ferrophosphorus and all other ferroalloys.

Demand for Metal Workers

Highly skilled metal tradesmen are now the workers in the greatest demand in New York State, according to the State Department of Labor. These include tool and die makers, boring mill and turret lathe operators, machinists, etc. The trend in some small plants is to increase their training and promotion plans.

American Tin Smelting

Everything points to the definite establishment of tin smelting plants in this country on a substantial scale. Bolivian tin ore or concentrates will be the principal raw material.

(Other "Trends" on page 116)

A few of the basic *individual* characteristics of both Cast Iron and Steel are listed. ***MEEHANITE*** castings offer you, through composition and structural control, a *combination* of these properties, permitting simplification of design and demanding no sacrifice of one in order to be assured of another.

Write for the property Wheel Chart. It tells you what you can get with Meehanite.

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trends

By Edwin F. Cone, Editor

Structural Material in Coaches

The trend in the incorporation of the low-alloy, high strength steels in "passenger coaches and body units" of articulated trains has been strikingly upward. The *Railway Age* recently published a table of such coaches and units, in which was given the structural material used. Out of 1874 such units, 51.06 per cent or 957 were built of mild-alloy steels or "H. T. Steel." Units in which stainless steel predominated made up 19.79 per cent with aluminum alloys as the principal material third at 13.02 per cent.

Streamlined Trains

The trend in the use of streamlined trains by American railroads has been gaining rapid momentum. *The Railway Age*, in its 1940 Passenger Progress number, shows that in spite of the millions of dollars spent for new streamliners prior to Sept. 1, 1939, many more millions have been spent since. The last year has been one of astonishing progress. It has seen 32 new, lightweight, streamlined trains completed and placed in service up to Nov. 1 involving a total of 203 cars. On the same date there were on order 26 trains also involving 203 cars.

In this large program metals and alloys play an important part—aluminum alloys; low-alloy, high strength steels; and stainless steels.

Steel Output Records

Late last year all indications pointed to new records in steel ingot production for 1940—an excess of 8 per cent over the 1929 record output; of 34 per cent over 1917, the peak in the World War period; and of 27 per cent over the 1939 total. The present trend is likely to be exceeded in 1941.

Air Conditioning Units

Self-contained air-conditioning units exported from the United States in September, 1940, totaled $116,236, a new high for 1940 and 48 per cent in excess of the outgo for August. Metals and their alloys enter largely into these units.

Air-Conditioning the Blast Furnace

Another large company is to have an "air-conditioned blast furnace." In the summer of 1939, the Woodward Iron Works, Woodward, Ala., created no little stir with the first installation of this type of equipment. It now has three furnaces so equipped. Now the Jones & Laughlin Steel Corp. announces the addition of air-conditioning equipment at one of the world's largest blast furnaces—No. 1 at its Aliquippa Works—capable of removing from 7 to 40 tons of water per day from the air blown into it. Maintaining a constant low moisture content in the air blast makes possible a more uniform charge, better control of smelting operations, and a saving in raw materials. This trend recalls the Gayley dry blast in the 1890's, using refrigeration to reduce moisture.

Leviathans of the Air

About 5 yrs. ago—on Nov. 22, 1935—the famous China Clipper soared away from San Francisco on the first scheduled passage of an ocean by air. Her sister ship, the Philippine Clipper surged away from the same spot 16 days later. Both ships were built by the Glenn L. Martin Co., Baltimore—leviathans of the air that "couldn't be built." The trend since then has been startling and progressive—similar leviathans cross the Atlantic and are now a vital link in transportation to Europe and back during the war. Research and production in metallurgy are a prime cause of these developments.

Safety Records

Some striking records are being made in safety by some companies. Completing 11 consecutive years without a lost-time accident, the chemical laboratory of the Gary steel works of the Carnegie-Illinois Steel Corp., has established a new safety record. This period covers more than 2,000,000 man-hrs. completed without an accident. Among the tasks involved is sampling of each blast furnace casting period, work in control laboratories at the open-hearths, over 7,000,000 quantitative analyses, and sampling thousands of carloads of raw materials and cargoes of iron ore and limestone.

Steel Casting Production

Output of commercial steel castings, as reported by the Department of Commerce, Bureau of Census, was at a much larger volume in 1940 than in 1939. The rate as of Nov. 1, 1940, was about 63,090 net tons per month as compared with 49,500 tons monthly for all of 1939. This trend is bound to expand in view of the Defense Program.

Electric Steel Castings

Data on the production of steel castings in the United States are not plentiful. The Department of Commerce, Bureau of Census, has recently published statistics for the output of commercial steel castings for 1939 and 1937. The total for 1939 was 722,769 tons against 1,249,164 tons in 1937. Of the 1939 total 34.8 per cent was electric and crucible (mostly electric) while in 1937 this proportion was only 27.9 per cent—another indication of the expansion in the electric furnace product.

(Additional "Trends" on page 114)